DATA PROCESSING

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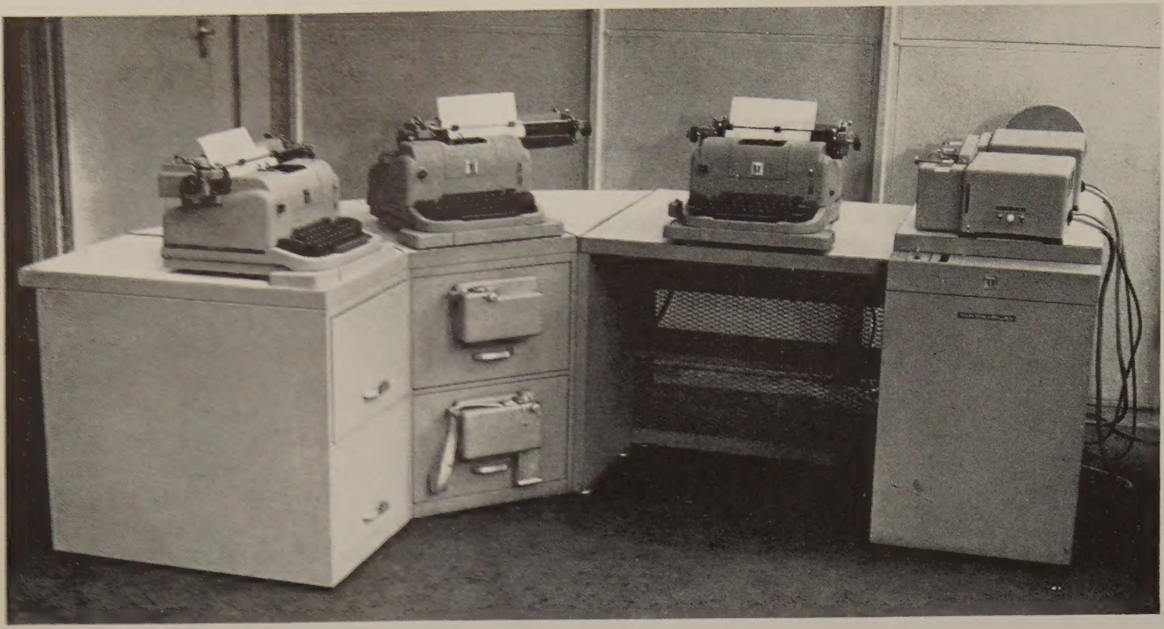


A typical Data-Flo system. All three typewriters can be operated automatically by punched paper tape

Automatic preparation of

Electric typewriters, adding machines, paper-tape punches and paper-tape readers linked together in a single system

A new system is now being marketed by Underwood Business Machines Limited. Multiple copies of documents are produced on several typewriters simultaneously—all under the control of one operator. Selected data are punched in paper tape to be reproduced, later, in a variety of ways on as many other documents as desired. Sub-totals and totals are compiled automatically and complex data processing sequences are performed under the control of a master programme. The equipment, how it works and what it achieves is described in the following article

DATA-FLO is the descriptive title given to a new data processing system that has recently been developed by Underwood Business Machines Limited. A number of electric typewriters, electric adding machines, punched paper-tape readers and paper-tape punches are linked together in a common system. The equipment was devised to fulfil the requirements of business and commerce for a flexible and versatile information handling system. It is the first system of its kind that can be controlled by a predetermined programme.

The design and operation of the system depends upon the fact that data manually typed on the keyboards of certain master typewriters can be punched in paper tape. Later this tape can be used to operate one, or all, of the other units. Data read from the tape can be printed simultaneously on a variety of documents or reproduced in edited form in another paper tape. A programme set up on a pre-wired plugboard or punched in paper tape controls the way in which the various units are interconnected and thus the particular data processing sequence performed.

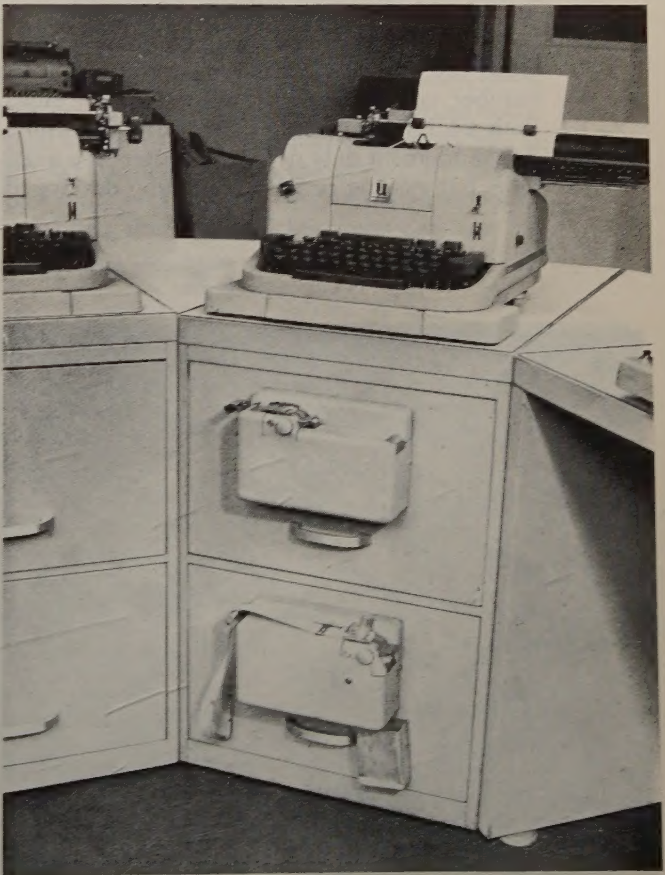
The description just given may seem to lack precision, but of necessity this is so because there is no one Data-Flo system. Each system is created from a number of separate units and the actual form a particular system takes depends upon the type of work it is required to do. The smallest system might consist of one electric typewriter and one paper-tape punch, whereas the largest system can contain up to three electric typewriters, two paper-tape punches, two paper-tape readers and two duplex adding machines.

Before the uses of the Data-Flo system are considered, the individual units will be described together with the four basic installations that can be built.

There are three designs of electric typewriter. One is called the Servomaster which, as the name implies, is the principal writing machine of the system. It can be operated automatically, typing data read from punched tape, or manually. In appearance it is similar to a conventional electric typewriter, complete with standard keyboard, except that it possesses two additional keys. These are placed one on each side of the space bar and are called programme keys. They are provided because at certain points in a data processing sequence it may be necessary for the operator to choose which of two alternative courses in the programme to follow. An example of how these programme keys are used is given later in the article.

Keyboard of the Servomaster typewriter

commercial documents

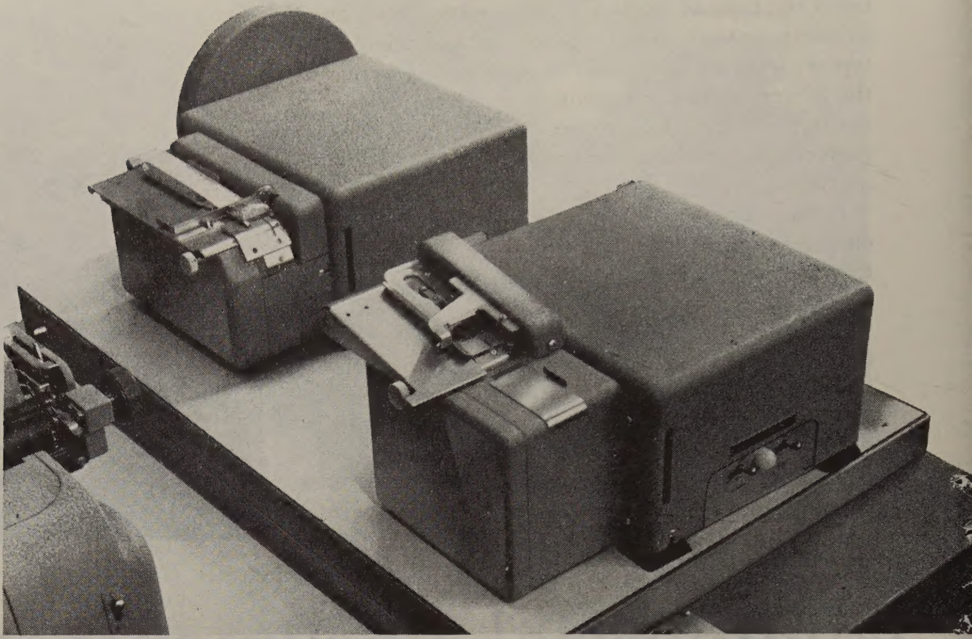


Beneath the Servotyper typewriter are a tape reader and a tape punch

A typewriter called a Mastertyper can be fitted to a Data-Flo system as an alternative to the Servomaster. It is similar to the Servomaster except that it is equipped with punching facilities only and therefore cannot be operated automatically by a tape reader.

All the other typewriters connected to a Data-Flo system are electric machines of conventional design fitted with electric circuits which enable them to be used as slave units. These machines are called Servotypers. Their primary function is to repeat entries made on the master typewriters or to type data read from tape.

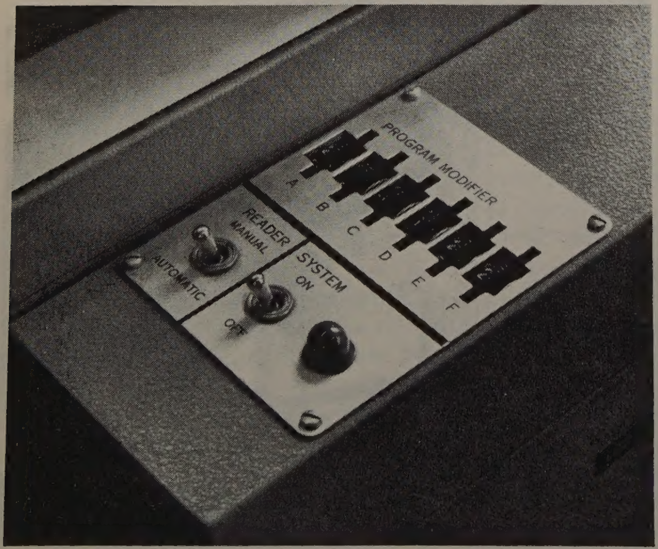
It has been mentioned that punched paper tape is the principal medium of communication in the system and reading and punching units can be fitted to handle 5-, 6-, 7- or 8-channel tape. These units can also operate with edge-punched cards in which data are recorded down one margin in the same punched-hole code used for the paper tape.



A second tape reader (in foreground) and a second tape punch can be included in the system. These units can handle edge-punched cards as well as tape

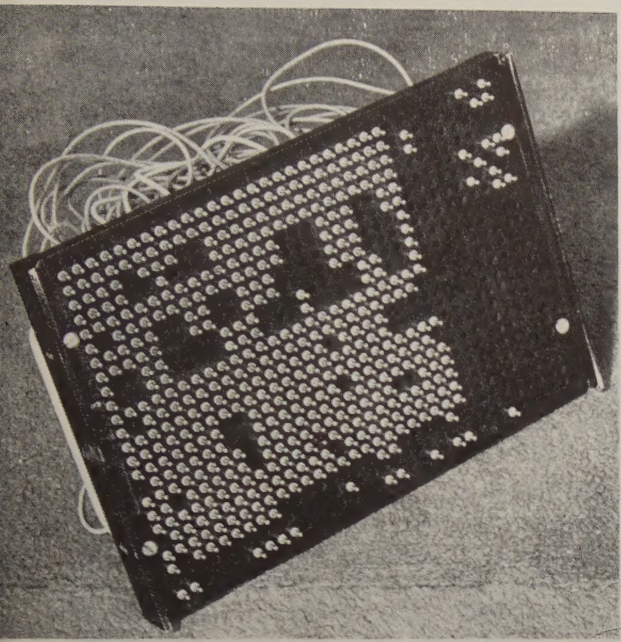
Lastly, duplex adding machines can be connected with the system. Two of these units may be fitted and each has two registers in which totals are recorded. Each register can store a number containing anything up to 11 digits. Both additions and subtractions are performed. At the moment only decimal registers are available, but sterling registers are being developed.

The six ten-position programme modification switches used to enter variable data



For convenience, all the units of one system are housed in a single desk unit, although there is no reason why the Servotypers or secondary tape punches and readers should not be located in other parts of the office, or even in other offices. Normally the Servomaster typewriter is placed in the middle with a Servotyper on the left. Below this, in the left-hand pedestal of the desk, is fitted a paper-tape reader and, at the bottom, a paper-tape punch. A second Servotyper can be placed on the right of the desk together with a second paper-tape reader and another paper-tape punch. The right-hand pedestal contains the electric circuits which connect the various units together and also the programme plugboard that controls the operation of certain types of Data-Flo system.

Fitted at the front on the right-hand side of the desk are the main operating switches. Included among these are six ten-position rotary switches called programme modifying switches. They serve several purposes. Perhaps the most useful is that they provide a means of specifying variable information that is to appear on a large number of documents. Such information might be the day's date or an identity number. In the case of the date, this is set on certain of the ten-position switches and the programme can be arranged to refer, when required, to the settings of the switches and to type the information recorded there.



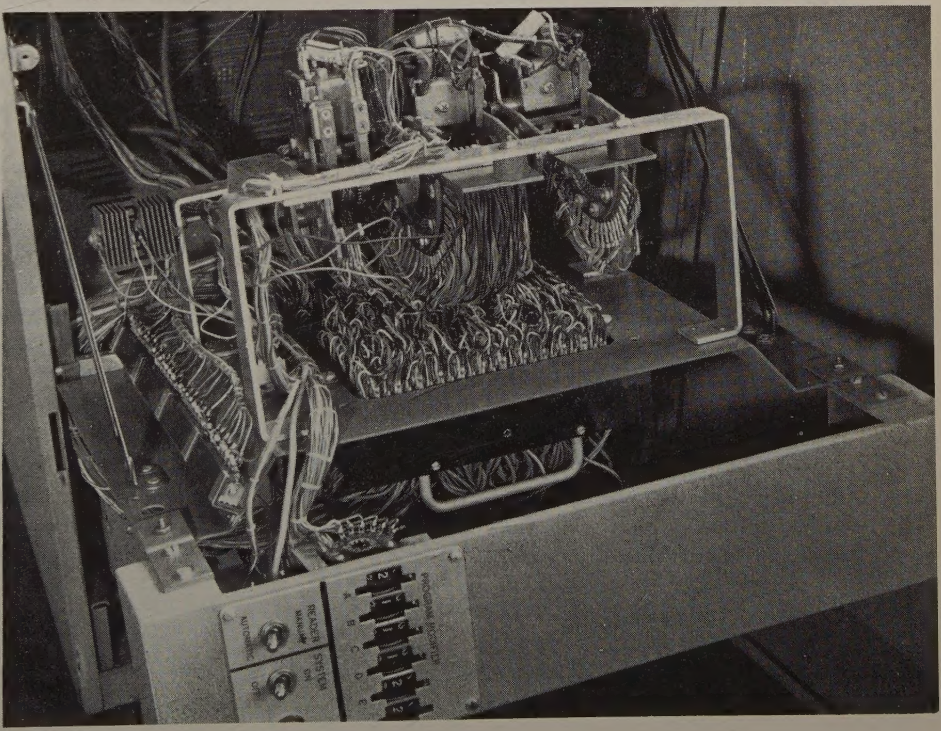
Programmes are established by fitting plugs in a board

These switches are also used to select the appropriate programme in those cases where several different programmes are recorded on the same plugboard.

There are four Data-Flo systems. The simplest consists of units permanently connected by a fixed electric circuit—this system cannot be programmed. Next, a system can be constructed where the electric connections can be altered in accordance with a prearranged plugboard programme. Programmes containing up to 88 steps can be performed. The third system is a larger version of the second and plugboard programmes containing up to 275 or 550 separate steps can be performed.

Lastly, a Data-Flo Tapemaster system is available. In this system the programme is punched into paper tape. It differs from the plugboard system in that, at the moment, not so many units can be controlled. The maximum number of units that can be connected together in a standard system is limited to four, a Servomaster, a Servotyper, a tape punch and a tape reader, or five if the Servotyper is omitted and replaced by an additional tape punch and tape reader. Advantages of the Tapemaster system are that it is more convenient to keep programmes on tapes rather than plugboards, there is no limit imposed on the length of a programme and it permits greater flexibility in the performance of a programme.

The variety of ways in which the Data-Flo units can be operated is extensive. To take a very simple case: as data are entered on the keyboard of the Servomaster a document is typed and if, at the same time, a Servotyper is connected to the main circuit, an identical document is typed simultaneously. Alternatively, it can be arranged that as the keys of the Servomaster are pressed, only the Servotyper responds and types the data. Other units can also be



High-speed stepping switches (seen at the top of the picture) control the performance of the programme brought into operation. As information is entered on the keyboard of the Servomaster, the data can be punched simultaneously into paper tape by either one or both of the tape punches. These in turn can be controlled so that only selected data are recorded. Finally, data can be read from punched tape by the reading units and reproduced in selected form by either one or all of the electric typewriters or tape punches.

It is the purpose of the programme to make sure that the correct units are brought into use at the correct time. In effect, what the programme does is to make the necessary circuit connections so that all the units required for a particular operation are working simultaneously.

The various steps in the programme recorded on the programme board are selected in sequence by stepping switches. These are high-speed units that take only 8 milliseconds (0·008 second) to move from one step to the next.

Instructions needed to control the action of the electric typewriters, such as carriage return and tabulate, are recorded in the punched paper tape, not on the programme board. The actual position to which a typewriter carriage moves when the tabulation signal is received is determined by mechanical stops preset on a tabulation bar similar to those fitted to conventional typewriters.

With a Tapemaster system the programme instructions recorded in tape are interspersed with the data or, if the system is provided with two readers, the programme can be read from one tape and the data from another.

Application of Data-Flo system

Perhaps the best way of indicating how these systems can be used is to describe one particular job that can be performed. The job chosen is the preparation of the documentation for a factory and a sales office as a result of orders received from customers. Each morning the batch of customers' order letters are gathered together and are examined to ensure that the credit limit for each customer will not be exceeded and that the items ordered can be identified and understood.

All the permanent information about a customer, such as his name and business address, is recorded on a short length of punched paper tape. A file of these customer tapes is maintained. The appropriate tapes are selected from the file and are attached to the customers' order letters which are then given to the operator of the Data-Flo system.

First, information obtained from each customer's letter has to be typed on to a works order form. This document provides the authority for the items to be either issued from stock or manufactured by the factory.

The operator prepares the machine by fitting the plugboard, containing the appropriate programme. Then she positions a blank works order form in the Servomaster typewriter. Naturally, where considerable numbers of orders are being prepared, continuous stationery is used. And lastly, she threads a blank paper tape through the punch. All is now ready for the transcription operation.

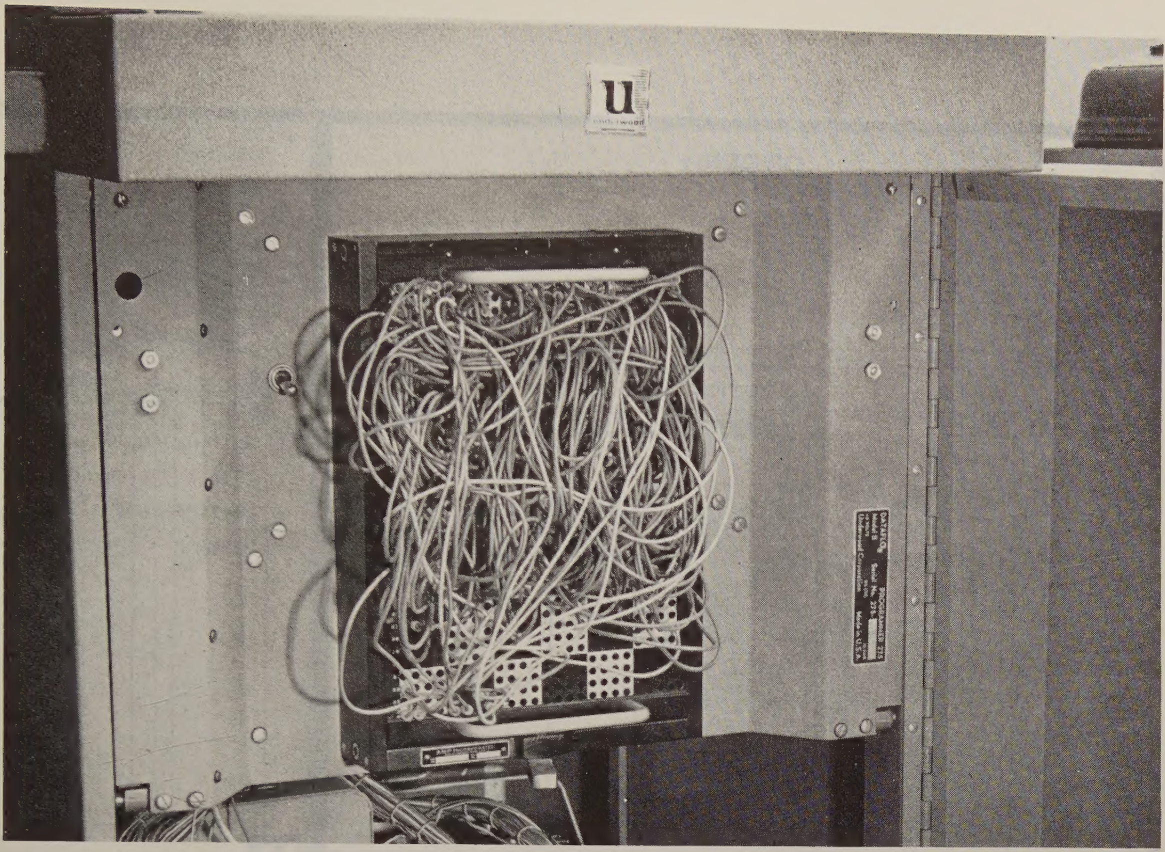
Preparing works orders

Taking each letter in turn, the operator inserts the accompanying punched paper tape into the reader and presses the "start" button. The first action performed by the programme is to switch on the tape reader. The customer's name and address, together with his reference number and other permanent data, are read from the paper tape and typed automatically at the head of the works order by the Servomaster typewriter. Next, the day's date, obtained from the programme modifying switches, is automatically typed and the form is positioned ready for the order number to be entered. As this is an item of variable data the operator types the number, using the keyboard of the Servomaster. Next, all the separate items requested in the order are typed manually on the Servomaster.

Throughout this operation the tape punch is switched on. Consequently the tape produced contains all the permanent data obtained from the customer's permanent data tape plus all the variable data that have been entered manually on the keyboard of the Servomaster. In addition, a properly typed works order has been prepared.

Proceeding in this way the operator deals with each order in turn, producing the equivalent works order plus a paper tape in which all the data are duplicated. The works orders are checked and sent to the factory for the goods to be manufactured and despatched. In the meantime, the information tape is filed in the sales office.

In due course the works orders are returned from the factory together with an account of the action taken. The majority of the items listed will have been manufactured and despatched to the customers, other items will have been supplied, but perhaps not in the quantities



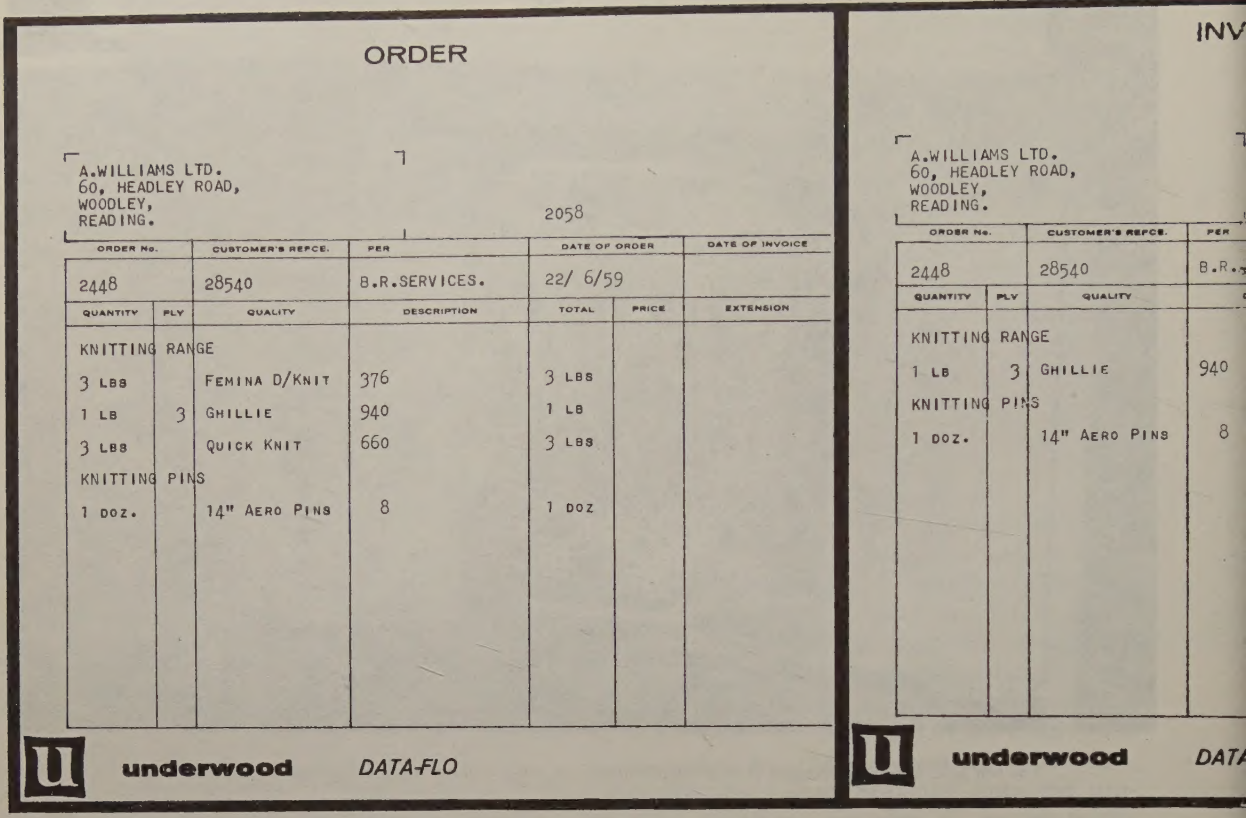
When jobs are to be changed it is a simple matter to replace one programme plugboard with another

required and some will not have been supplied at all because of, say, stock or material shortages. Now the invoices have to be prepared and posted to the customers. In addition, new works orders have to be created for those items not supplied. All these documents can be prepared automatically on the Data-Flo from the information tape punched when the original works orders were produced.

Before this is done, however, the prices of the items delivered are calculated and a total derived for each order. A desk calculator is used for this work. This information is written on the works order forms, which are passed, together with the information tape, to the Data-Flo operator. She inserts the information tape in the reader and places a blank invoice form in the Servomaster typewriter, a blank works order document in the Servotyper and blank paper tapes in the two punches. Selected data are to be entered on these latter documents, but the same data will not necessarily be reproduced in each.

With the correct plugboard programme panel fitted in the machine, the first customer's name and other data are read from the tape and printed at the head of the invoice and the new works order, together with the date. The Servomaster and Servotyper type these data simultaneously at 100 words a minute. Then the Servomaster prints on the invoice the order number that appeared on the original works order form. However, the fresh works order must be given a new number and so the Servotyper will be prevented from printing during this operation. The number of the new works order is entered manually on the keyboard of the Servomaster and the programme ensures that, in this case, only the Servotyper responds—the new number is not therefore printed on the invoice.

Next, each item on the original order form is reproduced on either the invoice or the new works order depending on whether it was delivered to the customer or not. This is an occasion when the operator makes use of the two programme keys. The machine stops at the beginning of each line. If the item has been delivered, the operator presses the right-hand key. Data regarding this item are read from the tape and the information typed on the invoice by the Servomaster, the Servotyper remaining



ORDER

A.WILLIAMS LTD.
60, HEADLEY ROAD,
WOODLEY,
READING.

2058

ORDER No.	CUSTOMER'S REFCE.	PER	DATE OF ORDER	DATE OF INVOICE
2448	28540	B.R.SERVICES.	22/ 6/59	

QUANTITY	PLY	QUALITY	DESCRIPTION	TOTAL	PRICE	EXTENSION
KNITTING RANGE						
3 lbs		Femina D/Knit	376	3 lbs		
1 lb	3	Ghillie	940	1 lb		
3 lbs		Quick Knit	660	3 lbs		
KNITTING PINS						
1 doz.		14" Aero Pins	8	1 doz		

underwood DATA-FLO

INV

A.WILLIAMS LTD.
60, HEADLEY ROAD,
WOODLEY,
READING.

ORDER No.	CUSTOMER'S REFCE.	PER
2448	28540	B.R.

QUANTITY	PLY	QUALITY	
KNITTING RANGE			
1 lb	3	Ghillie	940
KNITTING PINS			
1 doz.		14" Aero Pins	8

underwood DATA

On the left is the original works order form produced on the Servomaster typewriter. The two remaining documents are the invoice to the customer and a new works order to supply goods that are out of stock. The latter two documents are prepared automatically from data punched in paper tape

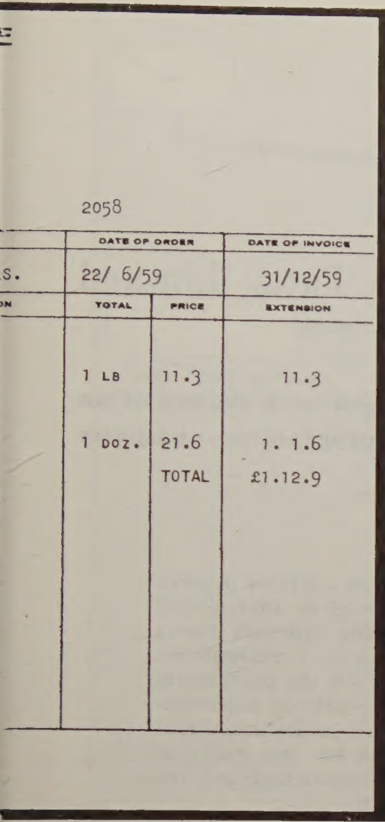
inactive during this phase. Then, to complete the invoice entry, the price is entered manually on the keyboard of the Servomaster. The carriage of the Servomaster returns automatically to the beginning of the next line and the system waits for the next instruction from the operator.

Suppose the next item was not supplied, then the operator touches the left-hand programme key. Immediately, data concerning this item are read from the punched tape and the information is typed by the Servotyper on the new works order and, this time, the Servomaster remains inactive.

Should part of the quantity ordered be delivered, the general descriptive data can be typed automatically on both the invoice and the new works order; the actual quantities are entered manually on each document, in turn. It will be appreciated that the programme keys are used to indicate to the machine which of the two alternative courses of action provided for in the programme are to be followed. The actions and the meanings temporarily ascribed to each key will, of course, be determined by the plugboard programme. In this way the system is endowed with a considerable degree of flexibility.

Every time data are printed on new works orders one of the punches is switched on and the information is recorded in tape. The work cycle described can then be repeated. Whenever invoices are printed, the second punch is switched on and selected data are recorded in a second tape. Data recorded are: customer's reference number, products bought, value and total value of order. Data on this tape are then transcribed automatically on to punched cards by a tape-to-card converter and analysed to provide sales statistics and accountancy figures.

The system described does not make use of any adding registers. As stated earlier, at the moment only decimal registers are fitted, though sterling units will be available in the



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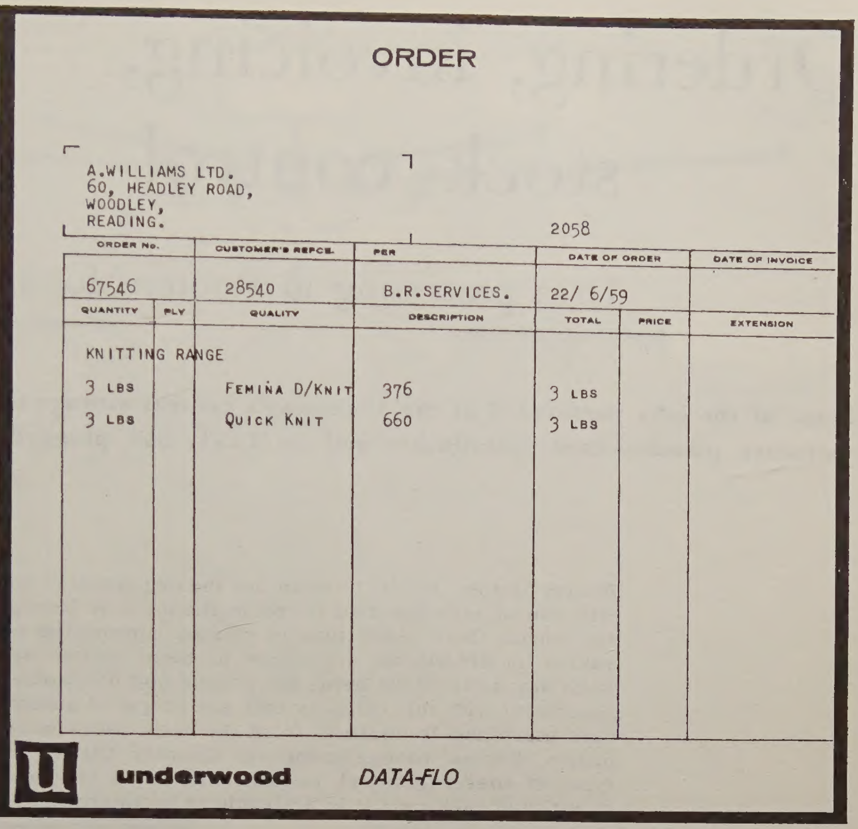
	DATE OF ORDER		DATE OF INVOICE
S.	22/ 6/59		31/12/59
ON	TOTAL	PRICE	EXTENSION
	1 LB	11.3	11.3
	1 DOZ.	21.6	1. 1.6
		TOTAL	£1.12.9



ORDER

A.WILLIAMS LTD.
60, HEADLEY ROAD,
WOODLEY,
READING.

2058

ORDER No.		CUSTOMER'S REFCE.	PER	DATE OF ORDER		DATE OF INVOICE
67546		28540	B.R.SERVICES.	22/ 6/59		
QUANTITY	PLY	QUALITY	DESCRIPTION	TOTAL	PRICE	EXTENSION
KNITTING RANGE						
3 LBS		FEMINA D/KNIT	376	3 LBS		
3 LBS		QUICK KNIT	660	3 LBS		

underwood DATA-FLO

near future. With these, cost sub-totals and grand totals will also be obtained and entered automatically on the various documents.

Occasionally it will be necessary to enter in the text of a standard statement an item of variable data. A special code is punched in the tape to halt the typewriter when this point is reached and the data are typed manually. However, if the space occupied by the variable item differs from document to document, the length of the typed line will—with any normal system—vary in a similar manner, resulting in a ragged right-hand margin. A special circuit has been fitted to Data-Flo to eliminate this effect. This circuit causes all typewriter carriage return instructions punched in the tape to be ignored when they occur in the wrong places. The circuit recognizes where a line should be broken and controls the typewriter accordingly. This is believed to be the first business machine system to incorporate this facility and so give mechanically produced documents that professional, uniformly neat, typed look.

Because of the many different Data-Flo systems that can be built, it is not possible to quote fixed prices. The range is from £900 for the smallest system (comprising, say, a typewriter and a tape reader) to £6,000 for the largest and most comprehensive system.

Underwood maintain a programming service for users with small installations. Where several systems are installed it is preferable, of course, for the firm to employ its own programmers and these are trained by Underwood.

Many office jobs are repetitive and machines can perform them competently and more efficiently than human beings. Productivity is improved because the electric typewriters operate tirelessly at ten strokes a second. In Data-Flo systems two programme keys are provided for those data processing sequences where human decisions are necessary. In this way, the system makes the best use of human intelligence, leaving the machine to perform those mechanical chores that always form such a large part of routine clerical work.

Ordering, invoicing, stock control

Data processing at Rootes Motors (Parts) Limited

Some of the jobs performed at the Company's central storage depot with the aid of an extensive punched-card installation and an I.C.T. 555 plugged-programme computer

Rootes Motors (Parts) Limited are the organization which supplies dealers with the spares needed for the maintenance of all Rootes vehicles throughout the world. Over 13,000 tons of spares, comprising 65,000 separate items valued at £10,000,000, are stored at their central depot in Birmingham. Each day up to 10,000 items are packed and despatched. All the documents associated with this complex task are prepared automatically on punched-card machines. In addition, from the basic data contained in the individual orders, Rootes' management can discover the demand for the different types of spare, the stock position, the value of stock despatched and the quantity of each part it is desirable to maintain in stock

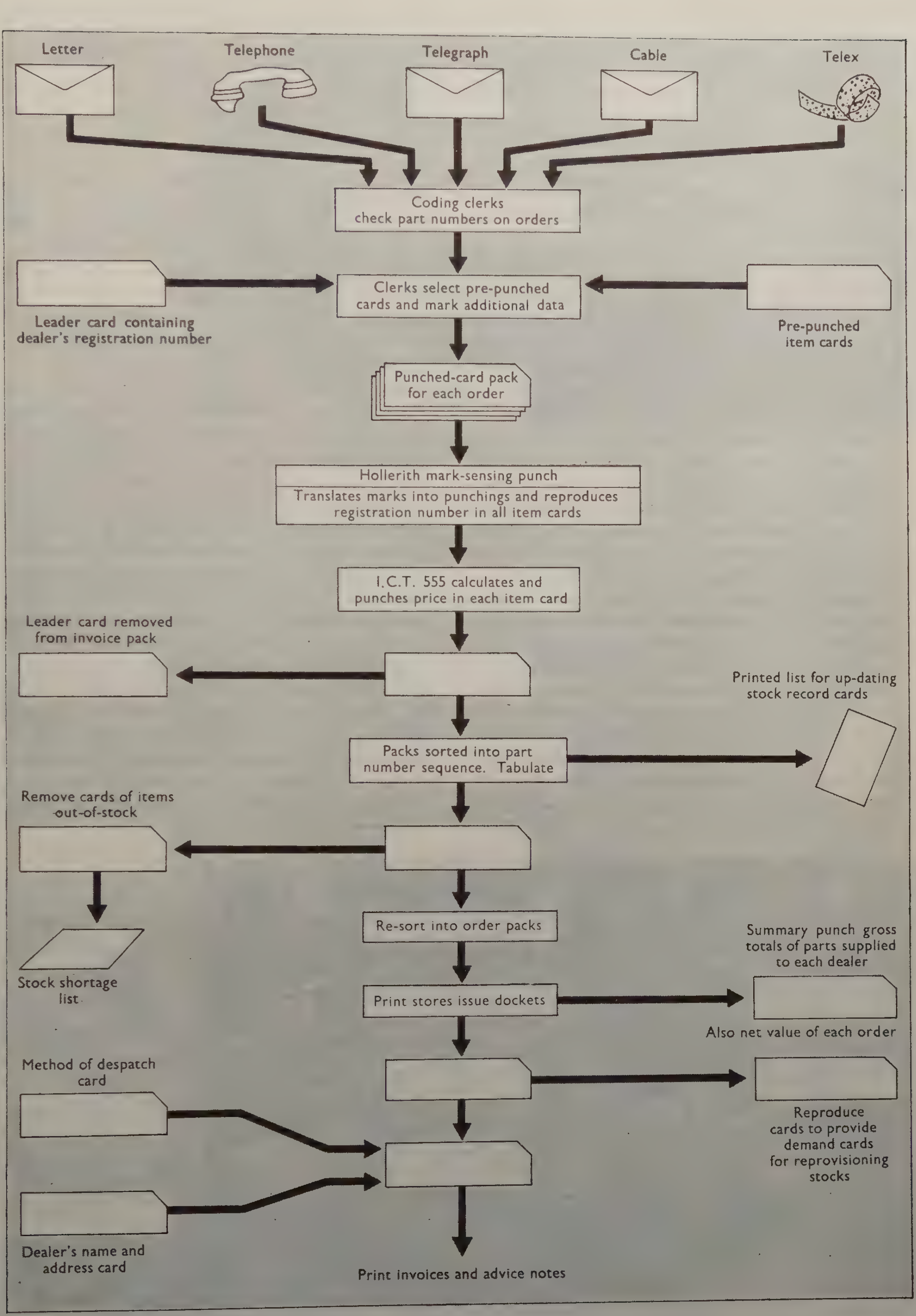
As many as 10,000 items are packed and despatched each day from the central spares depot of the Rootes organization situated at Small Heath, Birmingham. Any one of the 65,000 separate parts stored there, ranging from a packet of split pins to a complete lorry cab, may be required urgently, or to replenish the stocks held by a local dealer. Orders are received by post, telephone, telegraph, cable or Telex from dealers both at home and abroad. There are over 2,000 Rootes dealers in the British Isles, 800 in the U.S.A., 400 in Australia and many hundreds more in the other 160 countries of the world served by the organization.

Because a motor manufacturer's reputation rests, in a large measure, on the ability to provide promptly an adequate supply of spares whenever and wherever they are needed, Rootes have developed an organization that packs and despatches parts within 24 hours of an order being received. If the part is required urgently it is sent on its way in a matter of hours, by air if necessary. To do this not only does an efficient storage and despatch system have to be created, but, in addition, the paperwork connected with individual transactions has to be prepared with equal rapidity. An extensive I.C.T. punched-card installation is maintained for this purpose.

Among the many machines used are an I.C.T. 555 plugged-programme computer, four tabulators, four sorters, three collators, two mark-sensing reproducing punches, a gang punch, two reproducing punches and various other machines such as interpreters, verifiers and, of course, a number of key-punches of different types. About 90 people are employed in the department of whom 24 operate the machines. All the punched-card machines used are Hollerith.

Besides invoicing, a large number of other jobs are performed by the department. These include providing data on stocks that need to be replenished, sales statistics, facts for sales promotion and accountancy figures.

All these procedures, naturally, derive their basic data from the information contained on the orders received from the dealers. Each dealer sends in an order at weekly, fortnightly or monthly intervals, according to the volume of business transacted. To reduce the amount of clerical work a dealer is required to do he is supplied with a printed order form listing 3,000 of the parts in more frequent demand. Each part


Letter
Telephone
Telegraph
Cable
Telex
Coding clerks check part numbers on orders
Leader card containing dealer's registration number
Clerks select pre-punched cards and mark additional data
Pre-punched item cards
Punched-card pack for each order
Hollerith mark-sensing punch
Translates marks into punchings and reproduces registration number in all item cards
I.C.T. 555 calculates and punches price in each item card
Leader card removed from invoice pack
Printed list for up-dating stock record cards
Packs sorted into part number sequence. Tabulate
Remove cards of items out-of-stock
Stock shortage list
Re-sort into order packs
Summary punch gross totals of parts supplied to each dealer
Print stores issue dockets
Also net value of each order
Method of despatch card
Reproduce cards to provide demand cards for reprovisioning stocks
Dealer's name and address card
Print invoices and advice notes

number has six columns printed adjacent to it. Quantities of parts required are written in one of these columns against the item part number and the order form is returned to Rootes. When the order has been despatched, the form is returned to the dealer and the following order is recorded in the next free column. In this way the same form can be used for ordering parts on six different occasions.

A second order document is always returned with the form. On this document the dealer types particulars of any of the remaining 62,000 parts that he requires. Such is the nature of the motor business that these, as it were, "random" demands for the less popular spares account for a considerable proportion of each order. For this reason, the method of ordering by pre-printed forms is still regarded as experimental.

In addition to orders received in this way, others are sent in by post, telegraph or Telex. Over forty dealers throughout Europe can communicate directly with the Small Heath depot by Telex and many regularly transmit their orders by this method.

Upon receipt, the orders are sent to coding clerks who examine them to ensure that the parts required are correctly identified and, where this is not so, provide the identification needed.

Next, the order documents are passed to a group of clerks who assemble packs of 80-column punched cards—one pack for each order.

First, the clerks select a leader card containing the dealer's registration number. This is a special eight-digit number of which only the first three are the dealer's code number. Two of the remaining digits indicate usage and order type and the last three the order serial number. Usage covers the type of customer and the order serial number is a reference number supplied by the dealer.

Only the first three digits that identify the dealer are pre-punched in the leader card, and the clerk marks the five digits needed to complete the registration number. A special area on the card is printed with a pattern of rectangles containing figures and the clerk marks with a soft pencil (a 3B lead is used) the appropriate rectangles. Information recorded in this way is translated later into punched holes.

Having selected and marked the leader card, the clerk then moves to the parts file and selects one pre-punched card for each item appearing on the order. For this purpose, small packs of pre-punched item cards are stacked in part number sequence in a bank of open filing racks.

Data pre-punched in an item card are: bin number (indicating location of part in the store), part number, description of part, unit retail price, unit of issue (the smallest batch in which units are handled—normally one for large or expensive parts but may be in tens for nuts, washers and the like), discount code, source of supply and section, trade group code number and class of card. Source of supply and section specifies the department responsible for replenishing the stocks. Trade group code number indicates the type of part whether exclusive, competitive, reconditioned or a special accessory.

Over 40 dealers throughout Europe can communicate with the Small Heath depot by Telex. Many transmit their orders in this way

Selecting pre-punched item cards

Finally, the class-of-card code is a number that indicates the procedure to be followed during the subsequent data processing operations.

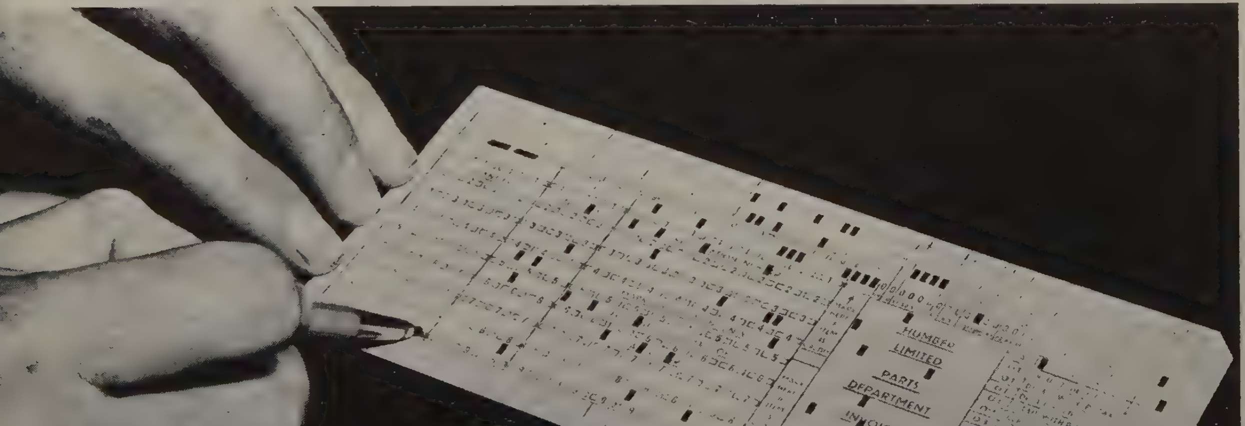
Space is also allocated on the item card for four further pieces of information that, at this stage, are not punched. These are the quantity ordered, net value, retail value, and dealer's registration number. Because this information differs from order to order, it has to be punched into each card individually.

As the clerk selects each item card she marks, with a pencil, the quantity ordered. This can be a four-digit number and the method of marking is exactly the same as that described earlier. Proceeding in this way, the clerk assembles a pack of cards for each order. On average, a clerk selects and marks 1,000 cards a day.

Next, the cards are passed on to other clerks who check that the correct cards have been chosen and that all additional data have been marked correctly. Incidentally, the cards have been designed so that they may be used either as leader cards or item cards.

The packs, or sets, are now passed on to a Hollerith 202/0 mark-sensing punch. This machine contains wire brushes which electrically sense the pencil marks made on the cards and translate the data into holes punched in the

Marking the quantity ordered on a pre-punched item card



cards. These holes do not necessarily have to be punched in the same areas as the marks. Cards are mark sensed at the rate of 6,000 an hour.

The first card in each set to pass through the mark-sensing punch is the leader card bearing the dealer's registration number. The last five digits of this number are mark-sensed, punched into the card and the card is ejected. As this is done, the complete registration number is recorded and stored in a register within the machine and this number is reproduced automatically in every item card of the set that follows. Also, as each item card passes through the machine the quantity pencilled on the card is mark-sensed and punched.

This continues until the next leader card is detected when the previous dealer's registration number is discarded and the new one is recorded in the machine to be reproduced in every item card of the set that follows.

From the mark-sensing punch the cards pass to an I.C.T. Type 555 plugged-programme computer. All the calculations needed in the preparation of the invoices are performed on this machine. The computer consists of three separate units: an input-output punch, a control desk and an electronic calculating unit. These three units are interconnected by electric cables. Data are read from standard 80-column punched cards by the input-output unit and the answers obtained are punched into cards by the same unit. Answers can be punched into the same card from which the factors of the calculation are obtained or into separate cards, as required.

Described as a plugged-programme computer, the I.C.T. 555 possesses most of the features of a conventional stored programme digital machine. It is equipped with a magnetic drum information store with a capacity for 105 computer words of ten decimal digits each. All four basic arithmetical operations (add, subtract, multiply and divide) can be performed in response to instructions contained in the programme. And, as the name implies, programmes for the computer are created by fitting plugs in detachable boards that can be changed quickly whenever the procedure is altered.

Operational cycle

An operational cycle proceeds as follows. A card travels from the input hopper into the machine where it passes through three sensing stations. Decimal data are read from the card at the first station converted into a binary coded decimal form and recorded on the magnetic drum. One track of the magnetic drum is used as a buffer store where data are held temporarily while being transferred between the input-output punch and the computing circuits. At the second station, data that will control the operation of the computer are read from the card. Finally, at the third station the numerical data originally read from the card at the first station are read once again and a comparison made. This provides a check on the correct operation of the unit.

After the reading sequence data are taken from the information store and sent to the arithmetic unit where the necessary calculations are performed under the control of the programme instructions set up on the plugboard. The results are then converted from binary coded decimal back into decimal form and transmitted via the magnetic drum buffer store to the input-output unit which records the answers.

I.C.T. 555 PLUGGED-PROGRAMME COMPUTER

The I.C.T. 555 computer was designed to provide punched-card installations with computational facilities. Punched cards are used both for entering data into the machine and for recording results. Cards are handled at rates of up to 100 a minute. A speed of 100 cards a minute is attained if the calculation can be completed in one operational cycle of the machine. Sometimes a calculation takes more than one cycle in which case, of course, the card handling rate is lower. For instance the sum of two numbers can be obtained and stored within one cycle ($\frac{13}{14}$ millisecond). Multiplication requires more than one cycle. The actual number of cycles depends upon the size of the factors. The machine is equipped with a magnetic drum information store that can accommodate 105 computer words containing ten decimal digits each. Extended calculations can be performed. Programme instructions which control the operation of the calculator are specified by arranging plugs in a panel. One programme can contain up to 150 steps.

The computer comprises three units—an 80-column punched-card data input-output unit; a console that houses the power supplies; and a cabinet containing the magnetic drum information store and the arithmetic unit.

Results of a calculation are punched into the card from which the original factors were obtained or into a separate card. Data can be punched in 60 of the 80 columns available on a card, leaving 20 columns free for gang punching reference data.

Factors used in a calculation may be obtained from the cards themselves or from the magnetic drum. Numerical constants may be stored on the drum for this purpose.

Code numbers read from the card at the second reading stage control the action of the machine. For example, the individual values of each item on an invoice can be added to various progressive totals stored on the magnetic drum. In this way extensive statistical analyses can be performed.

At Rootes, the 555 computer is used to obtain the net value and retail value of each item listed on an order and to punch these values in the first 14 columns of each item card. For the purposes of this calculation the following data are read from the card: unit retail price, quantity ordered, discount code, class of card and order type. The last three numbers indicate the percentage discount to be allowed and will ensure that the appropriate constants required for the calculation are selected from the information store. The retail value is obtained, of course, by multiplying together the unit retail price and quantity ordered. The net value is obtained by multiplying the gross retail value (just obtained) by the appropriate constant.

When these calculations have been completed, the leader cards are removed from the individual punched-card packs and the remaining cards are sorted into part-number order.

A printed list prepared from these cards by a Hollerith Type 854 tabulator shows all the items ordered that day. This list is then sent to a clerical section which is responsible for updating the stock record cards. National Cash accounting machines equipped with decimal keyboards are used for this work.

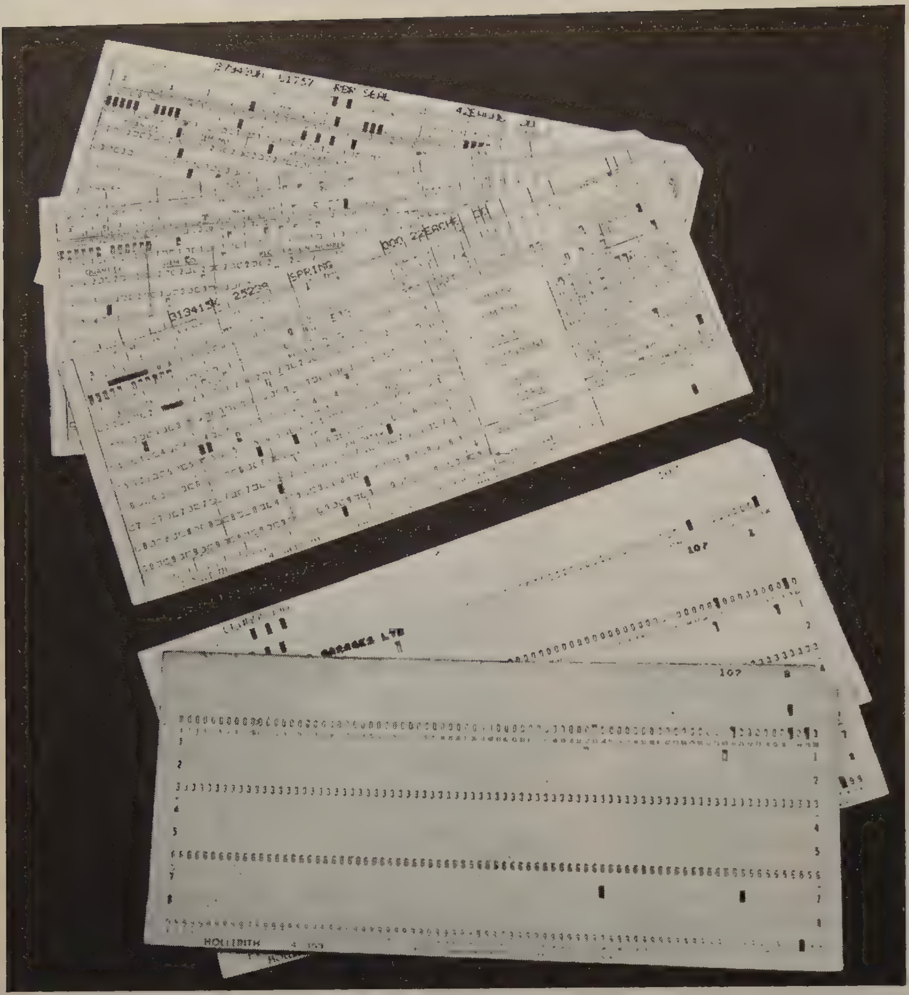
One stock record card is maintained for each type of part stored. No bin cards are kept in the stores. Consequently, the stock card is the only document on which a record is kept. A continuous and progressive audit is performed to reconcile quantities actually held with the quantities quoted on the cards.

Working from the printed list, clerks enter on the stock cards the number of parts ordered that day. A separate entry is made of the quantities required by each dealer, together with the dealer's registration number. After all the individual entries have been completed, the grand total of parts to be issued that day is deducted from the previous stock balance to give the new balance. The new balance is printed on the stock record card automatically; the accounting machine used to make the entries is fitted with adding registers in which the new total is compiled.

The stock control section is equipped with eight accounting machines and over 12,000 entries are made on the stock record cards each day. As about 10,000 items are issued every day the remaining 2,000 entries record the receipt of goods into store and other internal transactions.

One of the immediate and most important results of this operation is that it shows all those items that are out-of-stock. Obviously, it is no

The I.C.T. 555 *plugged-programme computer calculates the net value and retail value and punches these figures in the first* 14 *columns of each item card*



An invoice card pack. Above are a few of the item cards and below are the dealer's name and address card, a method-of-despatch card and a carriage charge card

use including these items on any invoices to be issued that day, so the corresponding punched cards are removed from the pack. These cards are then passed through a gang punch which perforates a code hole in all of them to indicate that the part is out-of-stock.

After these item cards have been removed, the remaining cards are arranged in dealer registration number sequence again and, at the same time—within orders—into bin location sequence.

Then the cards are passed through an 854 tabulator which prints the stores issue dockets. One docket is printed for each item on an order. In other words, one docket is prepared for each punched card that passes through the tabulator. On the docket appears the part number and description, bin location, unit of issue and quantity required, together with the dealer's registration number. Three copies of each docket are printed.

Afterwards a summary punch records, in cards, the gross values of each type of part supplied to each dealer. Each week a list is prepared from these cards to show the value of orders received and also the demand for the various types of spare.

All cards of items out-of-stock are then sorted into part number sequence and tabulated to produce printed stock shortage notifications. One copy is sent to the customer and the other to the progress department for urgent action to be taken. Values of these items are also summarized and recorded in punched cards.

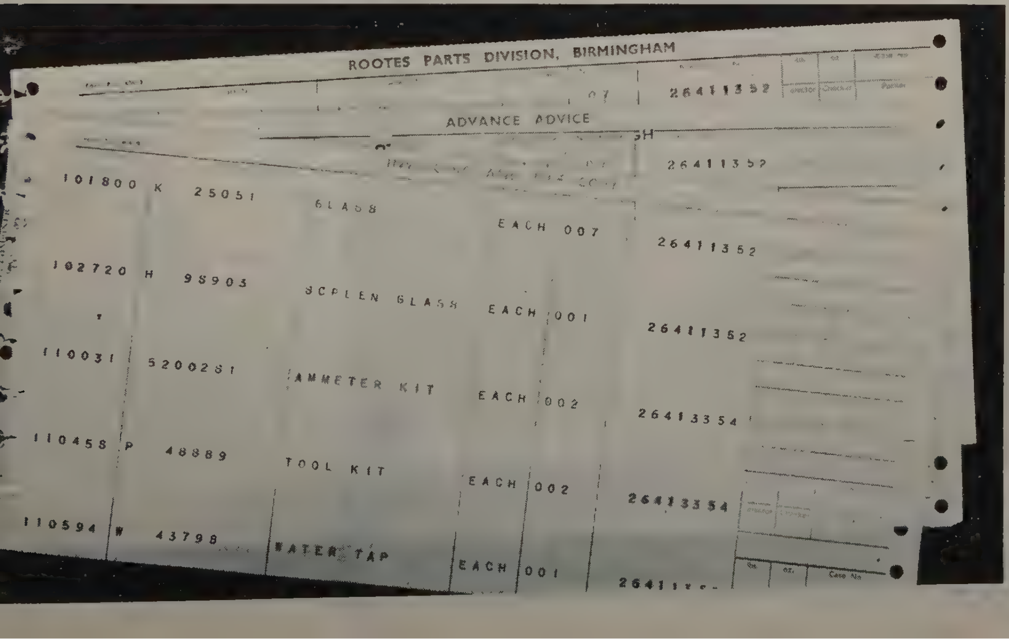
Although the dealer will not receive these goods with the other items, he need not re-order them because as soon as they are available they will be despatched to him and a separate invoice will be sent.

Next, the cards of all items in stock are reproduced and these duplicate cards—called demand cards—provide the basic data for the stores

Up-dating stock record cards on a National Cash machine

reprovisioning sequence about which more will be said later. After this, the original packs of punched cards are put on one side while the parts are gathered together and the orders packed and despatched.

Rootes Motors (Parts) Limited have converted a building that was once the Singer car factory to act as the central parts store for all vehicles manufactured by the group—that is, for Humber, Hillman, Singer and Sunbeam cars and Commer and Karrier commercial vehicles. More than 13,000 tons of spares valued at £10,000,000 are stored in an area of half a million square feet. The store has three main buildings. Block A contains packing and other consumable materials, together with certain bulk stores. Heavy parts such as engines, cylinder blocks and chassis frames are held in



ROOTES PARTS DIVISION, BIRMINGHAM

26411352

ADVANCE ADVICE

26411352

101800	K	25051	GLASS	EACH	007	26411352
102720	H	95903	SCREEN GLASS	EACH	001	26411352
110031		5200281	AMMETER KIT	EACH	002	26413354
110458	P	48889	TOOL KIT	EACH	002	26413354
110594	W	43798	WATER TAP	EACH	001	2641

Three copies of the stores issue dockets are produced on an I.C.T. 854 tabulator

Block C. However, the principal store is Block B. This is the largest of the three buildings and has six floors. Items stored on the higher floors are those for which there is a limited demand, such as pressings and large assemblies. Parts in greater demand, about 8,000 in number, are stored on the first floor nearest to the packing and despatch sections, which are located on the ground floor.

When the stores issue dockets have been prepared, they are sent to the stores control office on the ground floor of Block B. The first figure of the bin location number printed on each issue docket identifies the floor on which the part is stored. Dockets appertaining to one order are divided into batches and delivered in folders to their respective floors. Storemen select the parts and send them to the packing department on the ground floor by a chute that connects the first three floors. Items too large for the chute are sent by lift. When all the items for one order are gathered together in the packing department, the order is packed.

One of the carbon copies of the stores issue docket is printed on thin card and is attached to the actual part. Two paper copies are also printed. One set of paper dockets is included in the complete parcel and serves as a delivery note to the dealer. The remaining paper copies are returned to the machine accounting department to indicate that the order has been packed and despatched.

The packs of punched cards held in abeyance while the parts were being selected and despatched are then withdrawn from the file and any adjustments to the quantities supplied are noted. Possibly items are not in stock despite the fact that the stock record card indicated that they should have been available. When such a condition occurs, a stock audit is performed to discover the reason. After any adjustments of this nature have been made, dealers' name and address cards are withdrawn from a permanent record file and placed with the appropriate packs of cards representing complete orders. In addition, a method-of-despatch card (road, rail or air) and carriage charge card are also interleaved with each set of order cards. Everything is now ready for the preparation of the invoices and advice notes.

Cards arranged in invoice sets are passed through a Hollerith 854 tabulator which prints, on continuous stationery, the invoice (top copy), the advice note (carbon copy), the accounts department copy and the sales office copy (second and third carbon copies). While this work is being performed, the net value of each order is punched into a summary card by a summary punch connected to the tabulator.

Once a month, statements are prepared and sent to each dealer for payment. Printed statements are produced by first sorting the net value summary cards into dealer number sequence and then passing them through a tabulator. This action concludes the data processing sequence concerned with the supply of spare parts.

Data derived during this phase are used in many other data processing procedures. These include sales promotion, reprovisioning stocks, stock control and, of course, various accountancy sequences. For instance, a day-book of the value of all sales made is compiled automatically from the net value summary cards produced when the invoices were printed.

Accountancy figures

Another accountancy routine supplies management with a quick gauge of business activity. For this purpose, each week a statement is prepared listing the total value of goods received into store and the total value of parts issued.

The object of the sales promotion sequence is to maintain up-to-date records of each dealer's purchases. These are recorded under a number of different headings and provide a comprehensive picture of sales performance for each type of product in each of the world markets.

Replenishment of the stocks is yet another important data processing routine. It was for this purpose that demand cards were reproduced from the original order item cards. Demand cards are sorted into part number sequence and from them can be compiled the grand totals of parts issued. From this information management know what manufacturing orders must be placed with the factories within the group or with sub-contractors in order to replenish the stocks held.

Normally, the stock of spares is maintained at a level calculated to be sufficient to meet the average demand for a predetermined length of time. However, the situation is complicated by the fact that the average demand for a particular spare does not remain constant. It depends upon the number of vehicles on the road, the age of these vehicles and so on. Therefore, the nominal stock held must be adjusted from time to time to reflect these changes in demand.

In order that management can assess the position, a programme has been prepared for the

555 computer that works out whether the present stock held is sufficient. For this purpose the actual stock held of each part is recorded on punched cards together with progressive totals of the stock received and the stock issued. These figures are up-dated once a week. When the cards are passed through the computer the number of parts issued that week is added to the old total to obtain the new progressive total. This figure is then divided by the number of weeks over which the total has been compiled to give the average weekly demand. This average demand figure is used in two calculations to assess the current and future stock position.

The first calculation is to determine if a stock level sufficient to meet the average demand for a specified number of weeks is being maintained. The average weekly demand is multiplied by the specified number of weeks and the total obtained is subtracted from the current stock held. If a negative answer results, obviously it indicates that something less than the planned minimum is held and a special code hole is punched in the card. These cards are then sorted out of the pack and a list produced from them provides management with a stock shortage statement which shows the part numbers, together with the actual and minimum stock levels of all items in short supply. Immediate action is then taken to build up the stocks of these parts.

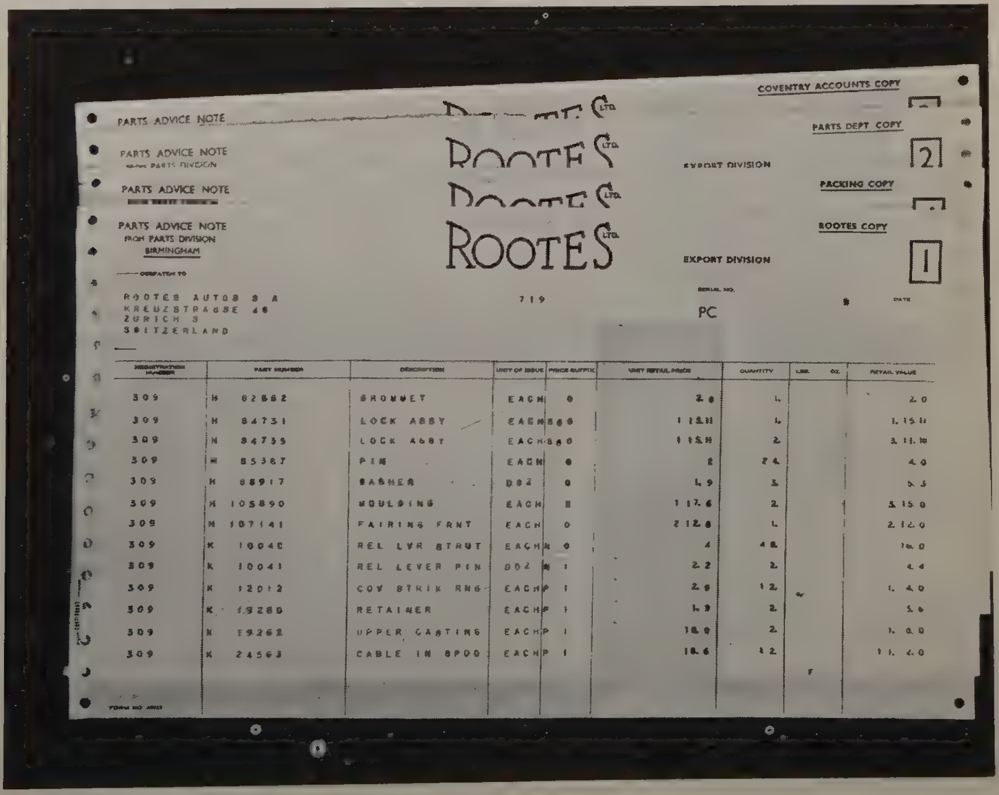
If this test is passed satisfactorily, a second calculation is performed to determine if the existing stock, plus parts on order from suppliers, will be sufficient to meet future needs. This calculation will also highlight items that have been over-ordered and for which stock levels will soon be too high.

Numbers of parts already ordered that are due for delivery within the next month are added to the current stock balance. This total is then compared with the average weekly demand and a list is prepared showing the part numbers and the weeks in which shortages or overstocking will occur. Also printed on the list are the future stock levels if the supply and demand for parts correspond with those forecast.

Once these factual data are obtained, steps can be taken to reduce the quantity held of those items over-stocked thus releasing capital that would otherwise be locked up needlessly, or to order parts to avoid a future shortage.

A sufficient number of the many clerical tasks performed by the punched-card department have been described to show how a series of interlocking data processing procedures takes care of all the paper-work connected with the ordering and supply of spares, and also provides management with statistics and accountancy figures that enable them to exercise effective control over the work. Of the many advantages obtained, one of the more important is that the capital invested in stocks is kept to a minimum without sacrificing in any way the ability to supply and deliver any spare at any time.

While the advice notes are printed, a summary punch connected to the tabulator records the net value of each order in a summary card



COVENTRY ACCOUNTS COPY
PARTS DEPT COPY
PACKING COPY
ROOTES COPY

PARTS ADVICE NOTE
FROM PARTS DIVISION
BIRMINGHAM

ROOTES LTD.

EXPORT DIVISION

1

ROOTES AUTOS S A
KREUZSTRASSE 40
ZURICH 8
SWITZERLAND

719

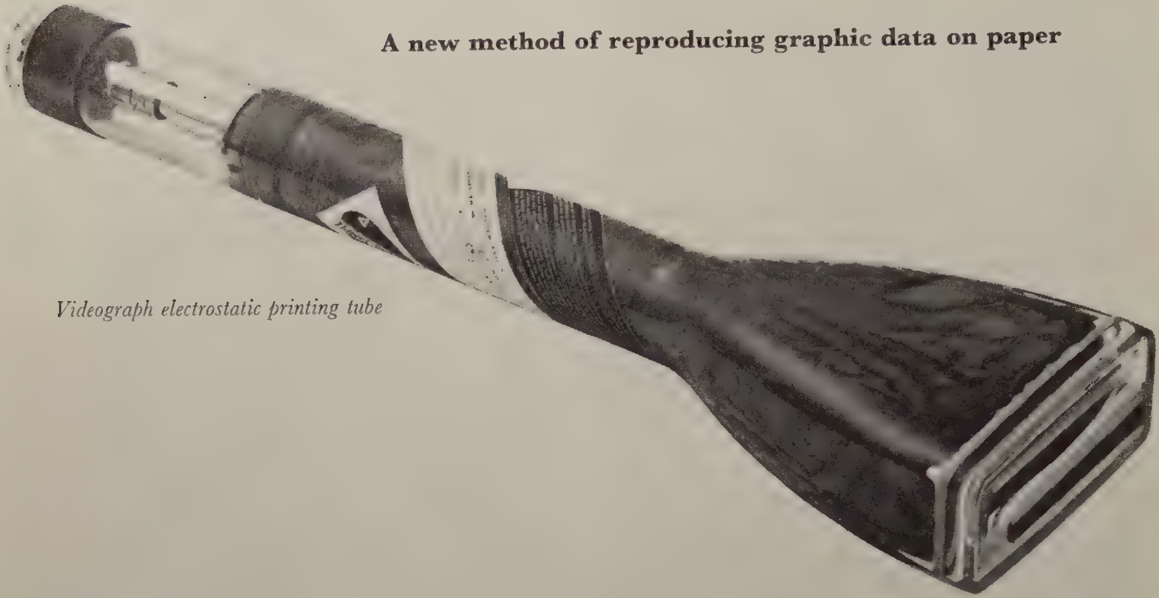
SERIAL NO.
PC

DATE

[illegible]	PART NUMBER		DESCRIPTION	UNIT OF ISSUE	PRICE SUFFIX	UNIT RETAIL PRICE	QUANTITY	LBS.	OZ.	RETAIL VALUE
309	H	82662	GROMMET	EACH	0	2 0	1			2. 0
309	H	84731	LOCK ASSY	EACH	860	1 15 11	1			1. 15. 11
309	H	84735	LOCK ASSY	EACH	860	1 15 11	2			3. 11. 10
309	H	85387	PIN	EACH	0	2	24			4. 0
309	H	88917	WASHER	DOZ	0	1. 9	3			5. 3
309	H	105890	MOULDING	EACH	0	1 17. 6	2			3. 15. 0
309	H	107141	FAIRING FRNT	EACH	0	2 12. 0	1			2. 12. 0
309	K	10040	REL LVR STRUT	EACH	N 0	4	48			16. 0
309	K	10041	REL LEVER PIN	DOZ	N 1	2. 2	2			4. 4
309	K	12012	COV STRIK RNG	EACH	P 1	2. 0	12			1. 4. 0
309	K	19260	RETAINER	EACH	P 1	1. 9	2			3. 6
309	K	19262	UPPER CASTING	EACH	P 1	10. 0	2			1. 0. 0
309	K	24563	CABLE IN SPOO	EACH	P 1	18. 6	12			11. 2. 0

Electrostatic printing

A new method of reproducing graphic data on paper



Videograph electrostatic printing tube

Videograph is the descriptive title given to a new process that can be used for either printing computer output data rapidly—at 20,000 characters a second—or transmitting graphic data from one point to another. The process is built round a new high-speed printing device developed by the Stanford Research Institute as a result of research sponsored by the A. B. Dick Company of Chicago, U.S.A. What this device is and how it operates is described in the article that follows.

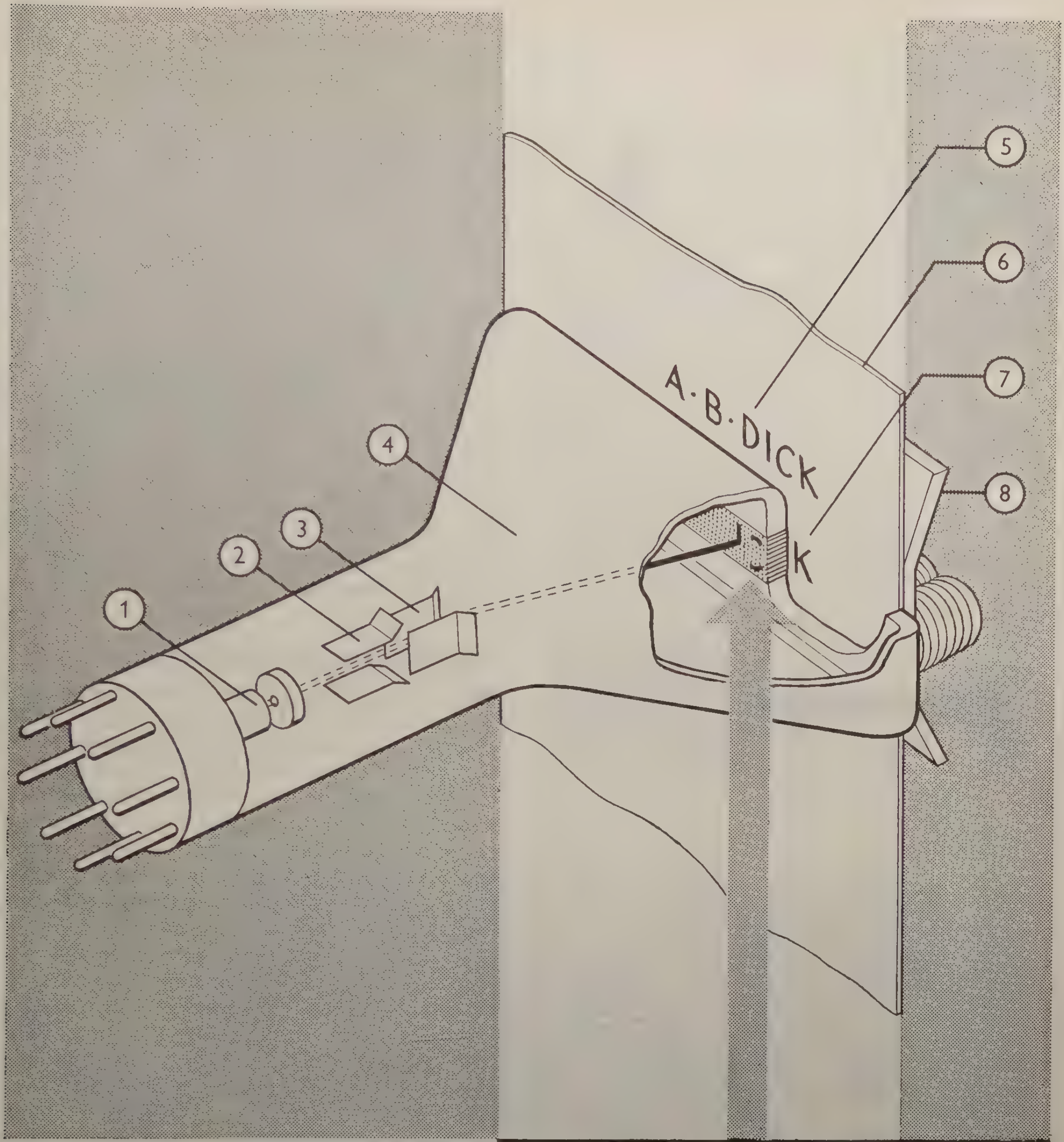
Some of the first Videograph data-transmission systems are to be used to record the movements of wagons into and out of railway marshalling yards, to reproduce facsimiles of waybills and other business documents and to print address labels for a publisher

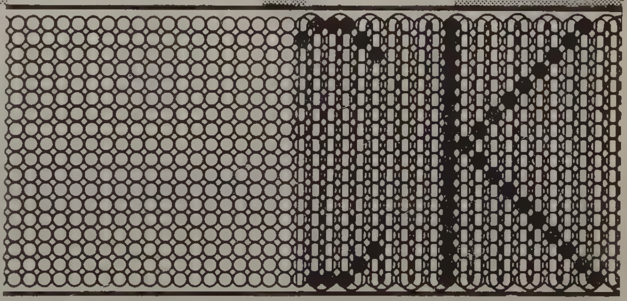
COMPUTERS are now being designed and built which can produce results at speeds well in excess of 60,000 characters a second. If the capabilities of these machines are to be utilized to the full, new techniques of handling and recording information are essential. While no method of printing at 60,000 characters a second has been evolved yet, some remarkable advances in this direction are being made.

Recently, in the United States of America, the A. B. Dick Company, of Chicago, announced the development of a machine that can print 20,000 characters a second. Digital data obtained directly from a computer, magnetic tape, punched paper tape or punched cards are decoded and printed on paper by a new device—an electrostatic printing tube. Although one of the principal applications for which this machine will be used is as a computer output printer, it is, in point of fact, part of a new high-speed facsimile data-transmission system known as the Videograph system.

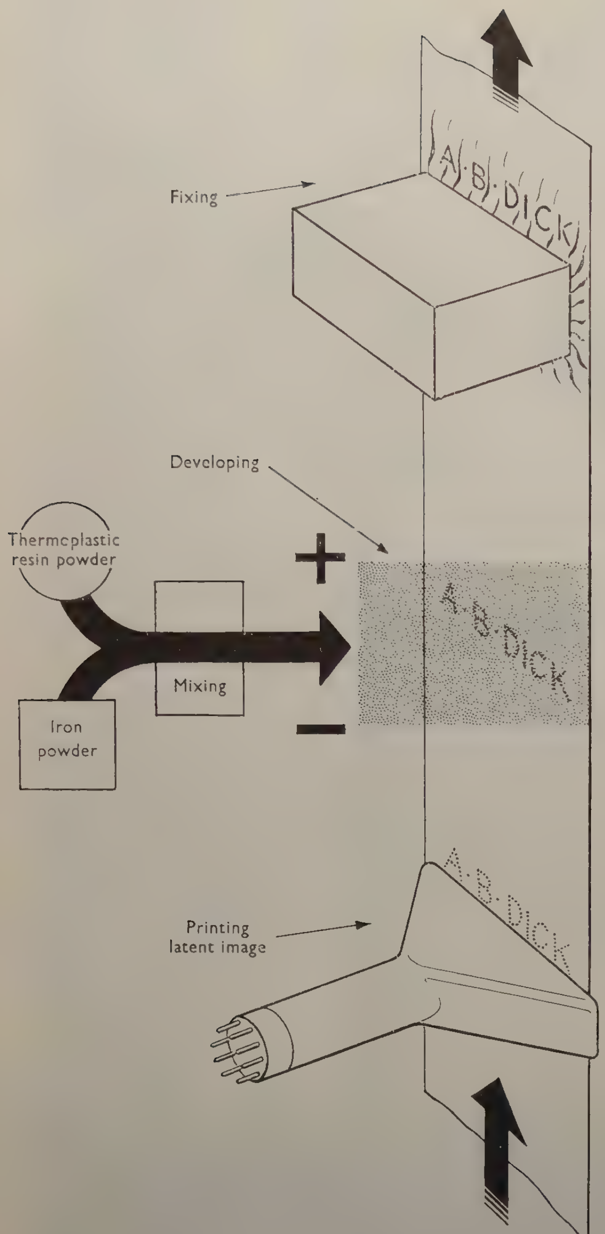
In this, documents to be transmitted are placed in a scanning unit which is connected to the printer by either landline or microwave radio link. Facsimiles of the original documents transmitted are reproduced instantaneously by the printer. Copies of both printed and pictorial data can be produced. A further interesting feature of this data-transmission system is its ability to print pictures of stationary or moving objects as seen by a modified television camera.

Because the method of printing provides the key to the Videograph system this will be described first. To print sequentially 20,000 characters a second is obviously beyond the capabilities of any known mechanical device (about 2,000 characters a second is the fastest





The electron beam projected along the tube is controlled to produce the outline of the character to be printed. Wherever the intensified beam strikes the end of a wire embedded in the tube, electrons are conducted along it and deposited on a sheet of paper held in close contact with the screen. In this way an electrostatic image is produced, on paper, of the character to be printed. This is shown in the lower illustration. The parts of the electrostatic printing tube are: 1, *electron gun;* 2, *vertical deflection plates;* 3, *horizontal deflection plates;* 4, *glass tube;* 5, *electrostatic image;* 6, *paper with dielectric coating;* 7, *wire matrix embedded in screen;* 8, *pressure plate*



Printing sequence. Proceeding from bottom of diagram to top: first an electrostatic image is impressed on the paper, then the latent image is made visible by sprinkling powder over it and, finally, the image is made indelible by heat

speed yet achieved), so the A. B. Dick Company sponsored a research programme at the Stanford Research Institute to devise an electronic method of high-speed printing. The printing head developed is of unique design. It is a modified cathode-ray tube, in the screen of which is embedded a large number of small-diameter wires. Each wire passes through the thickness of the glass screen so that while one end is exposed to the beam of electrons that are generated within the tube the other end is freely exposed on the outer face of the tube. Rows of wires are arranged across the face of the tube. The number of rows embedded in the screen must be sufficient to cover the maximum height of the largest character to be printed. This is the device that is called the electrostatic printing tube.

Before digital information can be printed it has first to be decoded. Data received from, say, a computer are sent to a decoder and character-generation unit. This unit controls the intensity of the electron beam as it is moved across the wire matrix in a series of short, vertical scanning strokes to form the outline of the character to be printed. Each character is decoded and generated separately.

Printing electrostatic image

Whenever the intensified beam strikes the end of a wire embedded in the face of the tube, electrons will be conducted along the wire to the outside of the screen and deposited on the surface of a sheet of paper held in close contact with the screen. The resulting pattern of the negative electrical charge impressed on the paper in this way corresponds to the outline of the characters written on the screen of the electrostatic printing tube.

To convert this latent electrical image into readable script, two further steps are necessary. First, the image is "developed" by dusting powder over the surface of the paper. The developer consists of a mixture of iron and thermoplastic resin, both in powder form. When these two materials are mixed together mechanically, they become charged with static electricity—the iron negatively and the thermoplastic resin positively. Consequently, as the developer is cascaded over the surface of the paper the thermoplastic powder is attracted to those areas bearing an impressed negative charge, while the iron powder, being negatively charged, is repelled from these regions. After the excess developer has been removed, the characters imprinted by the electrostatic printing tube are left delineated in black thermoplastic resin. The paper is then passed under a heater and the resin fused to form an indelible image.

When printing is being carried out at high speed, all the processes described are performed continuously. The paper is drawn past the printing head at a constant speed and in order to compensate for the continuous movement, the array of wires embedded in the screen is inclined at a small angle. In this way, straight lines of printed characters are produced on the paper.

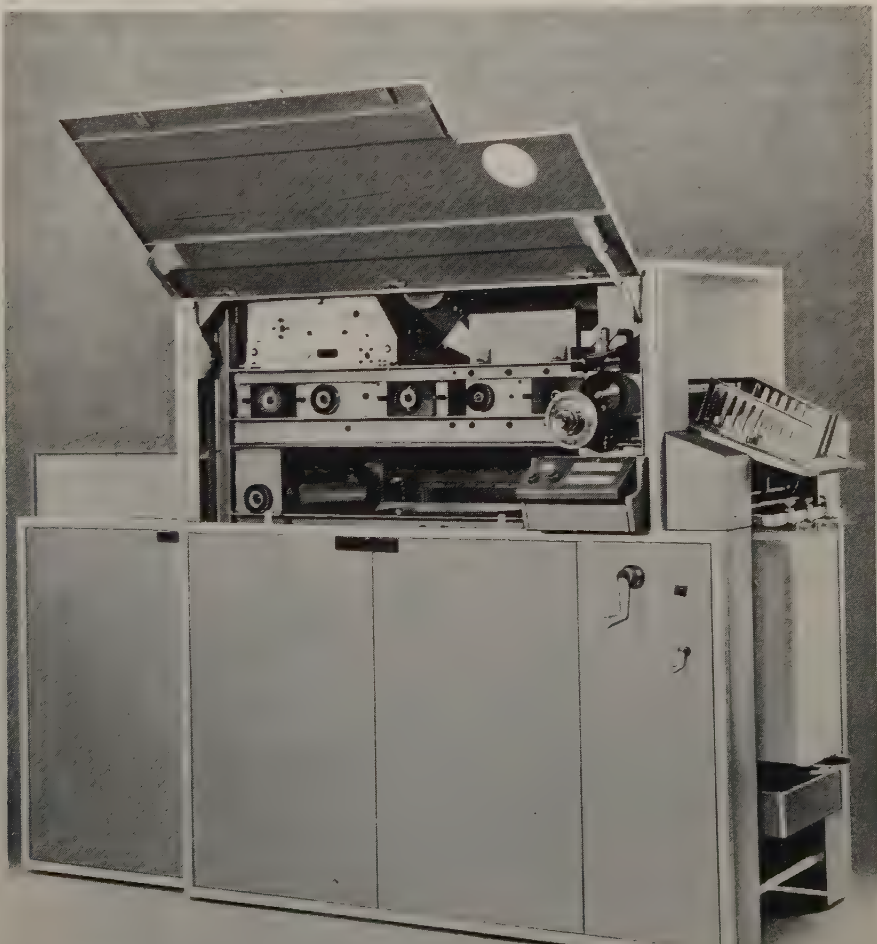
A special type of paper was developed for use with the electrostatic printing tube. A dielectric (that is, insulating) coating is provided on the surface brought into direct contact with the screen. This is to ensure that the electrical charge impressed on the surface does not leak away, otherwise diffused outlines are produced. However, to obtain crisp impressions of high contrast with a minimum of background haze it is necessary for the backing paper itself to be partially conductive. Paper can be provided with a glossy, matt, or semi-matt finish in a range of weights and sizes.

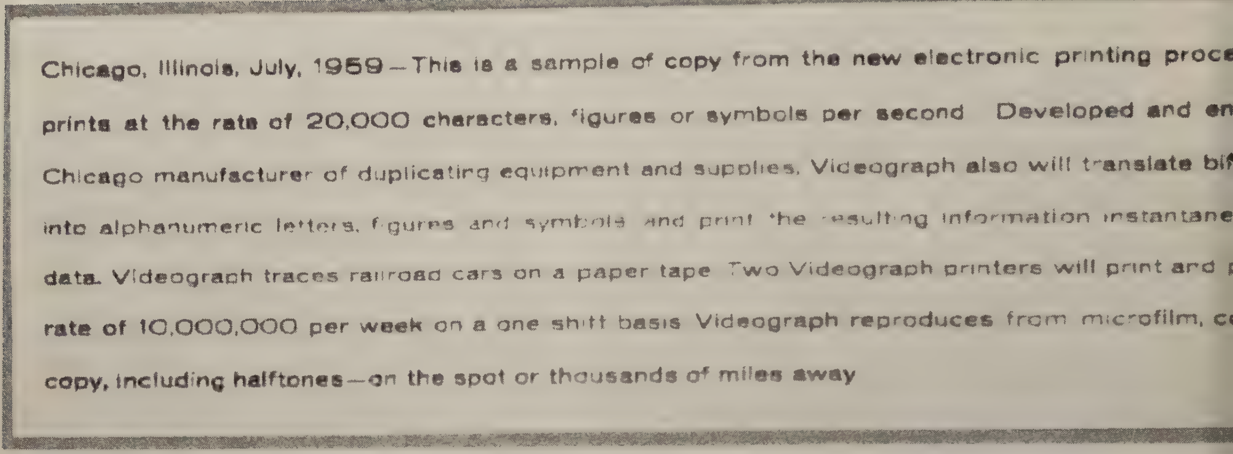
There are two ways in which the Videograph printer can be employed. Initially, one of the most important applications will be as a data output printer connected directly to an electronic computer (on-line operation) or to a magnetic tape or other data-transcription unit (off-line operation). Output data are printed at the rate of 200 lines a second on a continuous roll of paper which can be divided into sheets measuring 8½ inches by 11 inches. Each printed line may contain up to 100 characters; the vertical spacing of the lines is six to the inch.

The other way in which the Videograph printer can be used is as part of a facsimile data-transmission system. For this purpose a scanning or graphic data transmitter unit is available which can be connected with the printer by landline or, where distances are large, by a radio link. An electro-mechanical scanning system is employed which converts the image of the original document into a continuous electrical signal of the sort used in normal television transmissions. This signal is then conveyed to the printer by one of the two methods mentioned.

At the printer, the horizontal displacement of the electron beam in the electrostatic printing tube is synchronized with the horizontal rate of scan of the transmitter. In addition, the rate at which the original document is scanned in a vertical direction is identical with the speed at which paper is fed past the electrostatic printing tube. With both these actions synchronized, any

Videograph Model 905 *printer*





Chicago, Illinois, July, 1959—This is a sample of copy from the new electronic printing proce
prints at the rate of 20,000 characters, figures or symbols per second Developed and en
Chicago manufacturer of duplicating equipment and supplies, Videograph also will translate bi
into alphanumeric letters, figures and symbols and print the resulting information instantane
data. Videograph traces railroad cars on a paper tape Two Videograph printers will print and
rate of 10,000,000 per week on a one shift basis Videograph reproduces from microfilm, c
copy, including halftones—on the spot or thousands of miles away

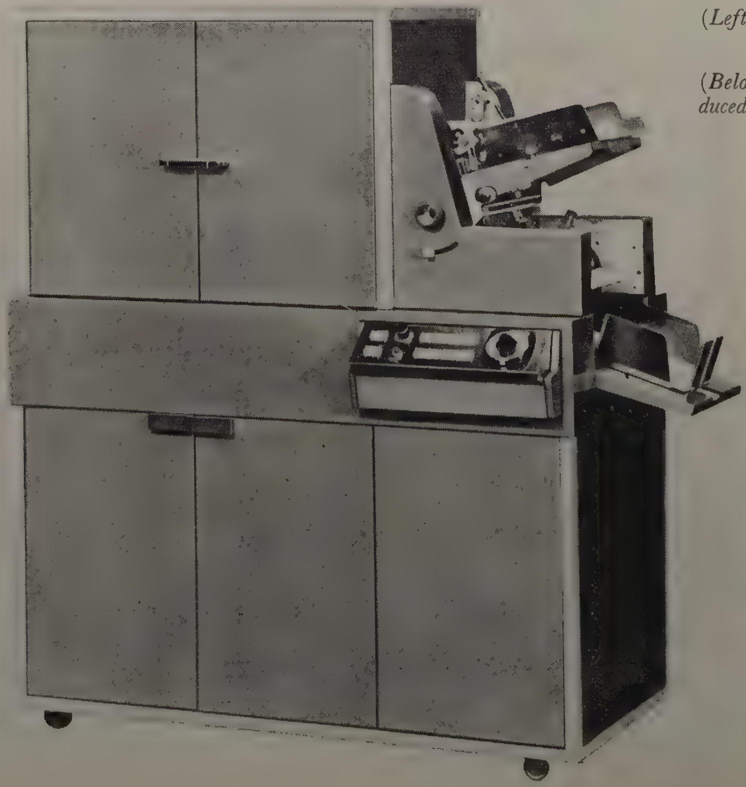
Facsimile of document produced by the Videograph electrostatic printer

variation in tonal value on the original document is faithfully reproduced on the printed copy. This means that not only can printed data be transmitted and reproduced, but also pictures.

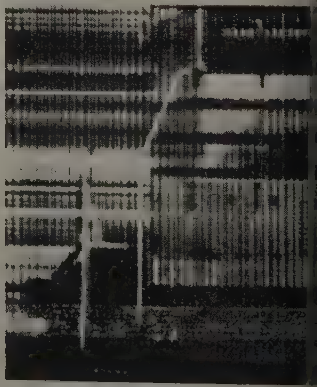
The version of the electrostatic printing tube used for facsimile reproduction differs from the computer output data character printing unit in that only a single row of wires spans the width of the tube. It has been found that for this particular purpose good results are obtained with a single row of stainless steel wires 0·001 inches in diameter spaced 0·004 inches apart.

Facsimiles of documents measuring 8½ inches by 11 inches are printed on a continuous roll of paper at the rate of three a second.

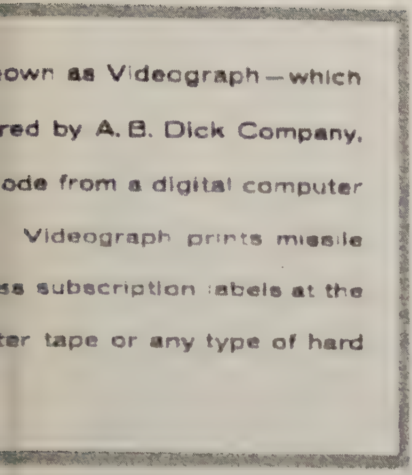
Another device that can be connected to the Videograph data-transmission system is a modified television camera. An interesting application of this equipment is to record the movement of wagons into and out of railway marshalling yards. A modified camera placed alongside the track is connected by landline to a printer at the railway traffic control centre. Wagon numbers, destination symbols, the time of departure and all other pertinent data are permanently printed on paper for immediate use or for the records.



(Left) Videograph Model 920 *scanner unit*



(Below, right) Printed record produced of a railway train moving at 15 *miles an hour*



own as Videograph—which

red by A. B. Dick Company,

ode from a digital computer

Videograph prints missile

ss subscription labels at the

ter tape or any type of hard

An investigation into the use of a Videograph system for this purpose has recently been completed for the New York Central Railroad System and further developments of the techniques are being considered.

Another railway application is the transmission of facsimiles of waybills and other documents recording the movement of goods trains between seven terminals. Each terminal will be equipped with a scanner unit and a printer, and data will be transmitted between them by a radio network. In the near future, a communication system of this type is to be installed by the Denver and Rio Grande Western Railroad Company.

A large publishing organization has also ordered two Videograph printers to prepare address labels. The printers will operate in conjunction with a computer equipped with magnetic tape decks on which the records of up to 10,000,000 subscribers will be stored. When address labels are to be prepared the required data will be read direct from the magnetic tape. All expired subscriptions and other unwanted information will be eliminated automatically and the data remaining—names and addresses of current subscribers—will be sent to the printers. These machines will then print the labels at the rate of 36 a second. As each printer is to be equipped with an automatic roll-changing and splicing mechanism, continuous uninterrupted printing is possible.

On completion of each week's run, the rolls of address labels will be sent to the publisher's various printing plants throughout the country where the labels will be guillotined off and automatically fixed to the magazines.

With both printers working one shift a day, over 10,000,000 labels can be prepared in a week. These machines cost approximately £48,000 each and will replace 18 machines now used for two shifts a day.

These, then, are a few of the actual applications for which Videograph systems and printers are to be used. Naturally, there are many other potential applications both in business and industry. Among these are the transmission and reproduction at district offices of copies of master documents of all kinds filed at central record offices (for example, insurance records, bank statements and cheques). Also the system could be used to maintain administrative control over a dispersed organization by the high-speed transmission of instructions to subsidiary organizations; these in their turn would send back operating information to the head office.

However, undoubtedly the biggest single application of the Videograph printer will be to record computer output data at 20,000 characters a second.

IBM computers

—the story of their development

That electronic digital computers could increase immeasurably the power and scope of mechanized data processing was obvious from the beginning. The question was, "Would it be worth it?" As IBM's main interest was manufacturing commercial data processing equipment, it was natural that the company should be associated with the development of the electronic computer from its inception. This article is the story of that development—indeed it is a short history of the computer that explains why the various types of machines were built. The fact that the account spans little more than ten years and yet includes descriptions of more than fifteen data processing systems, emphasizes the rapidity with which new ideas have been introduced

In the last ten years IBM has built and delivered more than 2,000 computers, ranging in size from small compact desk-type machines to extensive commercial and scientific data processing systems.

Contrary to normal engineering development practice, large electronic digital computers were built first, to be followed later by smaller, less powerful, machines. Four main phases in the development of automatic calculating machines can be distinguished. These are, in the order in which they occurred: the construction of electronic punched-card calculators; the building of large scientific computers; the adaptation of these designs to produce large commercial computers; the design of smaller specialized computers for both scientific and commercial use.

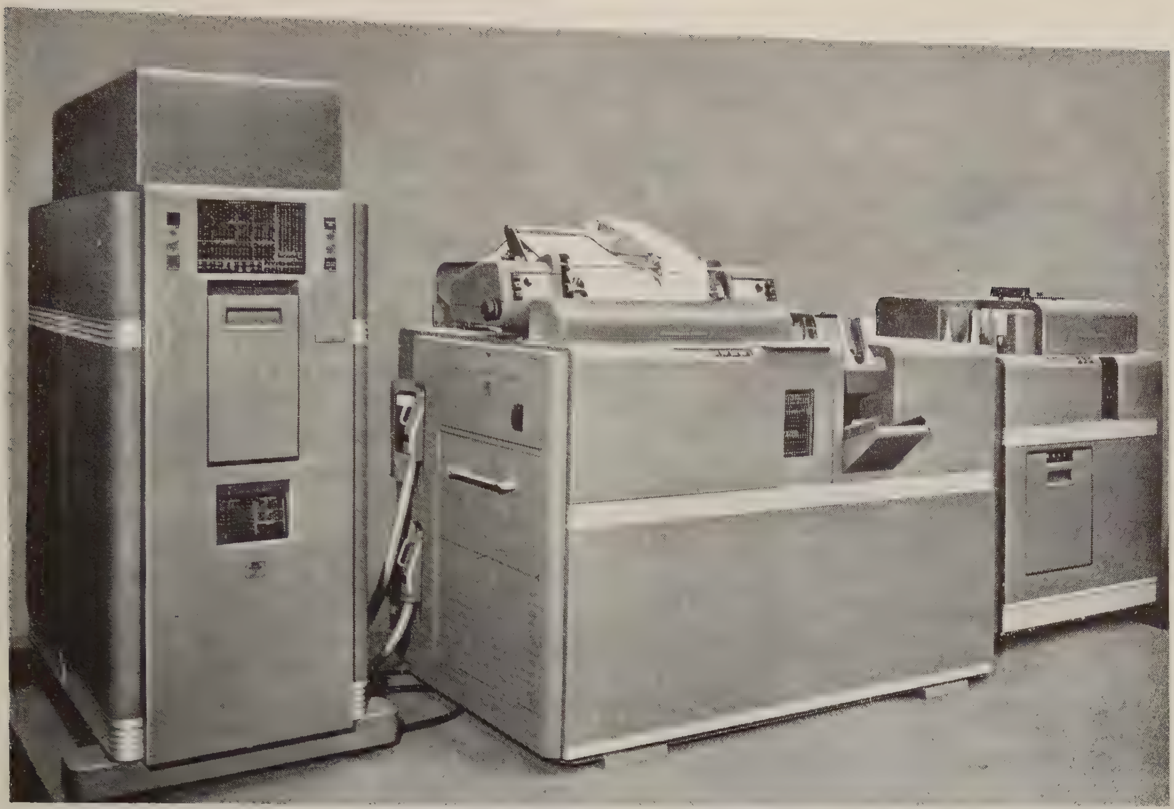
The first electronic digital computer—ENIAC—was built at the University of Pennsylvania in 1946, but the story as far as IBM is concerned starts before that date. Towards the end of the war, IBM built a machine called the Automatic Sequence Controlled Calculator (sometimes referred to as the Harvard Mark 1). This machine, constructed largely from existing punched-card mechanisms, was not a computer in the modern sense of the word because computations were performed mechanically, but it could carry out, entirely automatically, extended and complex calculations. On completion in 1944 it was installed at Harvard University.

Then, in 1948, the Selective Sequence Electronic Calculator was built. It could produce 250 times as much work as the Automatic Sequence Controlled Calculator. It was a large and expensive machine—it cost £330,000—and it possessed many features now associated with modern computers. About 400,000 digits of information could be stored internally and a fast arithmetic unit was fitted. Additions and subtractions were performed at the rate of 3,500 a second. However, maintenance must have been a problem as the machine contained over 12,500 valves and 21,400 relays.

Although this was the second large calculating machine to be built by the company, IBM were by no means certain at that time that there was a future for these machines other than for very specialized military or scientific applications. As a result, after the Selective Sequence Controlled Calculator had been built, research into electronic computing methods was not pursued quite so vigorously.

Nevertheless, active work in another direction was proceeding. In 1946, at the instigation of Mr. T. Watson, Jnr., now President of the International Business Machines Corporation, an electronic device constructed in an IBM research laboratory was put into production. This was an electronic multiplying unit that could be connected to a gang punch. Two numbers read from a punched card could be multiplied together and the answer punched in the same card. This machine appeared on the market in 1946 as the IBM 603 multiplier and more than 10,000 were sold.

A new class of machine—the punched-card calculator—stemmed from the 603. Calculators possess many of the features of computers except that they cannot follow such lengthy pro-



An IBM 421/604 *electronic accounting group*

grammes and have limited information storage capacity. A calculator is usually employed to perform one calculation that is part of a more extensive computational procedure.

However, at least one modern punched-card calculator is fitted with a magnetic-core store and a fast arithmetic unit and consequently bears a close resemblance to the smaller electronic digital computers. In fact, it is often left to the manufacturer to decide which machines shall be graced with the title "computer" and which given the more plebeian name of "calculator."

Many different calculators were developed from the 603 in the design laboratories. Of these, three were finally put into production and marketed. In ascending order of power they are the IBM 626, IBM 604 and IBM 628.

Various other standard punched-card machines can be connected to a calculator to make a more versatile data processing group. The first of these systems to be constructed was called the Card Programmed Calculator. An input-output punch, an accounting machine (sometimes referred to as a tabulator) and an information storage unit were all connected to the cabinet that housed the electronic arithmetic unit. With this assembly, output data could be printed as well as punched and the provision of additional information storage capacity enabled more complex calculations to be performed. It was developed primarily for scientific work and over 200 were built.

This punched-card machine system has now been superseded by others. One of these is known as the IBM 421/604 electronic accounting group. The 604 consists of an electronic calculating unit connected to a gang punch. To these units is connected a third—the IBM 421 accounting machine. Input data are read from punched cards by the 421 accounting machine, the calculations are performed in the electronic calculating unit and the results may be punched in cards by the gang punch or printed on documents by the 421. Pre-wired plugboard panels containing up to 70 programme steps can be fitted to the machine.

In 1958 the most powerful punched-card calculator yet produced by IBM was announced. This machine approaches that ill-defined boundary which divides computers from calculators. Like the 604, it can be included in an electronic accounting group. But the remarkable feature about the IBM 628 is that a magnetic-core information store of 320 digits capacity is fitted—something that has only recently been introduced on computers. The great advantage of a magnetic-core store is, of course, that access to any data recorded in the store can be obtained immediately.

Additions and subtractions are performed by the 628 in 180 microseconds (0·00018 second) and multiplication in 8 milliseconds (0·008 second). And the plugboard programme can accommodate up to 160 steps. Also it is possible to select any part of the programme to suit both the type of card passing through and the particular calculation to be performed.

Punched-card calculators cost between £615 and £22,000 and, by providing automatic calculating facilities, considerably increase the scope of an existing punched-card installation.

Although during the latter years of the 1940s the Company was rapidly developing bigger and better punched-card calculators, work on large electronic computers was still proceeding, though more slowly. Undoubtedly this was because in those days computers were conceived to be big machines and, on this basis, the number thought to be required did not justify the large capital investment needed for their development.

Prototype business computer

By 1950, however, a machine called the TPM (Tape Processing Machine) had been built and was undergoing tests. Designed specifically for business use, the machine was equipped with magnetic tape, magnetic drums and an electrostatic quick-access store. But in the rearmament drive that followed the outbreak of the Korean war the emphasis shifted from business to science, and IBM considered that the best contribution it could make would be to take up, once again, the development of large-scale computers for scientific and military purposes. And this point really marks the beginning by IBM of serious and intensive work on electronic digital computer development.

The first machine produced as a result of this renewed interest was the IBM 701. Nineteen were built and they were all installed in the United States of America, where a few are still in use to-day. The 701 is 25 times faster than the Selective Sequence Electronic Calculator, yet only one quarter the size. In March, 1953, the first production model of this machine was installed at the Company's headquarters in New York in the room formerly occupied for five years by the Selective Sequence Electronic Calculator. The 701 is equipped with two of the information storage devices still in common use to-day—the magnetic drum and magnetic tape. Information to which immediate access is required is stored in electrostatic storage tubes—a type of cathode ray tube. The popularity of the latter device has since declined and its place has now been taken by magnetic cores.

In the 701, multiplications are performed in 500 microseconds (0·0005 second) and 16,000 additions or subtractions are completed in a second (0·0000625 second each). Results are printed out at the rate of 150 lines a minute or punched into cards. Data to be held on file are recorded on magnetic tape at a speed of 12,500 digits a second.

Another interesting feature of the 701 is that it can perform "floating point" calculations. In this connection, it will be recalled that, within a computer, data are handled in small groups called "words." A computer word is usually of fixed size and can accommodate a certain number of digits. "Floating point" means that the decimal point in a number stored in a computer word does not have to appear in one fixed position. Instead it can move or "float" to suit the magnitude of the number. The advantage of floating point operation is that when long numbers are being handled there is less likelihood of significant digits being lost from the "ends" of the computer word because there is insufficient room to hold the last few figures.

The 701 is a powerful calculating machine, but, being designed for scientific work, understandably it did not prove suitable for commercial work. In fact, the 701 is described as a "scientific" machine.

Classification of computers

Computers are usually called either "scientific" or "commercial," but in this context the words have different meanings from those given in the dictionary. "Scientific" means that the computer is designed to perform long repetitive numerical calculations. Only a small amount of initial data are required and only a small quantity of results are produced. Consequently, scientific computers perform arithmetical calculations at high speed and are provided with relatively slow data input-output units. Also, internal information storage capacity need not be large.

In contrast, "commercial" indicates that the computer can store large quantities of data and is provided with fast data input-output units capable of handling punched cards, punched paper tape, and, in more recent years, magnetic tape. In addition, a commercial computer can handle alphabetical data as well as numbers. And, as fewer calculations are performed, much less emphasis is placed on the speed at which the arithmetic unit operates.

From these descriptions, it is apparent that the two words indicate the type of calculation the computer is best fitted to tackle rather than the type of job. This is why some commercial jobs can be performed, quite efficiently, if not better, on "scientific" machines than on "commercial" machines. In general, however, each class of computer can better perform that work after which it is named.

First commercial computer

Shortly after the 701 was produced, a start was made on the IBM 702, the commercial equivalent of the 701. The first machine was completed and running at IBM's Poughkeepsie research laboratories by April, 1954, and in March, 1955, a production machine was installed at the Monsanto Chemical Company, St. Louis.

Compared with the 701, the 702 has greater information storage capacity, a more varied range of data input and output devices, a more comprehensive list of programme instructions, and it can handle alphabetical as well as numerical information. Data are recorded on magnetic tape at a speed of 15,000 characters a second, and in 1955 a printer operating at 1,000 lines a minute became available.

Production of the 702 has now ceased, but two of these machines are still in regular use.

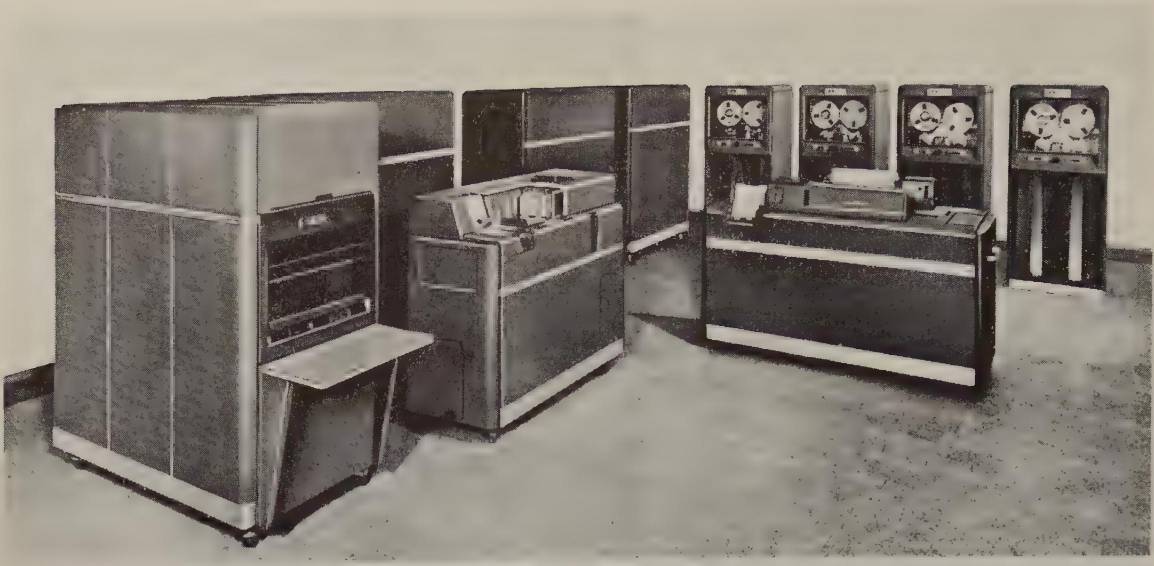
Development work continued and in 1956 two new computers were announced, one scientific the other commercial—the IBM 704 to replace the 701 and the IBM 705 to replace the 702. The major differences with respect to their immediate predecessors were that greater internal information storage capacities were provided, faster arithmetic units were fitted and the range of programme instructions extended. Also, for the first time, magnetic cores were used as immediate access stores, replacing the electrostatic tubes of the earlier machines.

As the 705 is a commercial machine, all information is handled in alphanumeric form—that is, each character, whether it is a decimal digit, alphabetical letter, punctuation mark or other symbol, is represented by a code group of six electrical pulses or bits. As many as 64 different characters can be uniquely identified by a 6-bit code. Within the computer, each 6-bit code group is treated as an entity; the individual bits are never handled separately.

Although a 6-bit code is very useful—in fact, essential when handling alphanumeric data—for numerical calculations, higher working speeds are attained if all figures are recorded in binary form. Therefore, data in the scientific 704 may be handled in either pure binary or 6-bit coded form.

No fewer than three different models of the 705 computer were developed. Model 1, which is now no longer built, was equipped with a magnetic-core store of 20,000 decimal digits

In 1954, *IBM's first large-scale commercial computer—the* 702*—was built*



An IBM 650 *computer equipped with four magnetic tape units*

capacity. Model 2 is provided with a larger capacity immediate access store of 40,000 decimal digits; this machine is being manufactured in both France and the U.S.A. And, later still, in 1957, the IBM 705 Model 3 was announced. It differs from the earlier models in several important respects. First, an immediate access store of up to 80,000 decimal digits can be fitted. Secondly, a faster arithmetic unit is provided; additions are completed in 88 microseconds (0·000088 second) instead of the 116 microseconds (0·000116 second) of Models 1 and 2. But perhaps the most important feature is the data synchronizer. This unit controls the operation of the magnetic tape decks and permits them to operate at the same time as calculations are being performed by the central data processing unit. If two or more data synchronizers are fitted, input data can be read from one magnetic tape, the results recorded on another tape and calculations performed, all simultaneously.

General-purpose computer

The next large computer to be designed and built by IBM was the 709 and, in 1959, the first production machine to be delivered in Europe was supplied to the United Kingdom Atomic Energy Authority. The 709 is the most powerful valve computer produced by IBM and represents a peak of development in this direction. It is classed as a general-purpose computer—that is, a machine that can be used equally well on scientific or commercial work. Thus the two separate paths of development, started with the scientific 701 and the commercial 702, come together in this machine. In practice, however, it is probable that 709s will be used more for scientific than commercial work.

A 709 is equipped with a magnetic-core information store where data are recorded in binary form and the machine can store the equivalent of 327,680 decimal digits. Magnetic drums may be fitted to provide additional data storage capacity to which access can be obtained reasonably quickly. Two numbers are added together in 24 microseconds (0·000024 second). Three data synchronizers may be included in a system, and each synchronizer has two channels for transferring data to or from the central data processing unit. Eight magnetic tape units can be connected to each data synchronizer channel to give a full complement of 48 tape units. In addition, a card reader, a card punch and a printer can be connected to one channel of each synchronizer to provide a maximum of nine data input-output units. The six data synchronizer channels allow six units to be operated simultaneously while calculations are being performed.

A new magnetic tape unit was introduced with the 709 computer. It automatically checks the accuracy of information recorded on tape immediately it has been written. If an error is detected the tape is stopped, reversed and the information is rewritten.

About 300 Series 700 computers are in use throughout the world to-day.

The first computers built were all large and complex. Applications could be found in science and industry, but the machines were far too big for the average commercial firm, especially firms sceptical of the worth of these new electronic devices.

In order to be able to offer a machine more modest in both size and price, early in 1955 IBM introduced the 650 general-purpose computer. Classed as a medium-sized computer, the 650 can be bought for £70,000 upward. In contrast, a 700 Series computer costs between £300,000 and £1,000,000.

A feature of the 650 design is that, initially, a start can be made with a small installation comprising three basic units. As confidence is gained and the volume of work increases, units can be added to this basic installation. In its smallest form, the 650 is slightly more powerful than a 628/421 electronic accounting group, while the larger versions of the system approach the capabilities of small Series 700 installations.

In many respects, the 650 can be compared with the Model-T Ford. It has provided numerous firms with their first experience of electronic computing and being a reliable robust machine, it has exorcized fears to which the words "electronic computing" gave rise. Well over a thousand 650s are in service throughout the world. The design is now obsolescent and is being replaced by new systems such as the IBM 7070. Consequently the total number in service is now falling, but undoubtedly 650s will still be performing useful work in ten years' time.

Optimum programming

As already stated, the basic 650 computer consists of three units. The first cabinet contains the power supplies, the second the magnetic drum information store and the third is a punched-card data input-output unit. With a capacity of 20,000 or 40,000 digits, the magnetic drum is the only information storage device fitted to the basic machine. The arithmetic unit is relatively slow. Additions take between 0·8 and 3·1 milliseconds (0·0008 to 0·0031 second) to complete largely because information is not immediately available—it first has to be obtained from the magnetic drum. However, by means of a programming technique known as optimization, the data can be arranged on the drum so that arithmetical operations are performed at the faster, rather than the slower, speeds.

Among the units that can be connected to the basic 650 system to increase both its speed and capacity are a data output printer, a second punched-card data input-output unit, an automatic floating-decimal unit and, another aid to programming, three indexing registers that can be used to modify programme addresses.

To improve the speeds at which calculations are performed, a 60-word magnetic-core immediate access store may also be connected to the system. Machines fitted with this store may, in addition, be equipped with up to six magnetic tape decks which read or record characters on tape at the rate of 15,000 a second. Lastly, provision is made to fit a special type of random access store called the IBM 355 Ramac. A description of this unit is given later in the article. The largest 650 installation that can be built contains 25 units.

Transistor computers

In 1948, a new electronic device was invented—the transistor.* And by the early 1950s transistors were being produced in considerable numbers. In 1956 IBM built a transistor calculator—the 608—and towards the end of 1958 they announced their first complete transistor computer—the 7070. The latter possesses all the now well-known advantages of transistor machines. It is smaller in size than the equivalent machine equipped with valves. Power requirements are reduced considerably—in some cases by as much as 70 per cent. It does not generate so much heat and is more reliable in operation. Ultimately the transistor machines will replace valve computers. In recognition of this fact, transistor machines are often referred to as "second generation" computers.

The 7070 is a general-purpose computer in the medium-to-large category. In the IBM range of machines it comes between the 650 and the 700 Series computers in both size and power. Additional units can be connected to the system as required and up to six input-output data synchronizers can be fitted (two for punched-card equipment and four for magnetic tape and Ramac storage units).

One great advantage of fitting data synchronizers is that they eliminate the need for independent data transcription units. Data can be transcribed from punched cards to magnetic tape and vice versa by the computer units without interfering with the main programme running on the computer. This procedure is referred to by IBM as SPOOL (Simultaneous Peripheral Operations On Line).

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*See "Transistors," *Data Processing*, October-December, 1959.

Another feature of the 7070 is that two programmes can be run together. One is designated as the main programme and has priority over the secondary programme. If the main programme is held up temporarily, because some unit such as a card reader is not ready, the 7070 automatically switches to the secondary programme. When the unit causing the delay becomes available the computer returns immediately to the main programme. In this way, two programmes can be performed simultaneously and the machine is used more efficiently. To obtain the best results, the two programmes should be complementary, one requiring large volumes of data to be read in and printed out, associated with few calculations—and the other involving considerable numbers of calculations and little in the way of input and output data.

In the 7070, data are held in a magnetic-core store of 50,000 or 100,000 digits capacity. The provision of such large immediate access stores enables data to be handled rapidly. To provide supplementary storage capacity, a total of four Ramac units and up to 40 magnetic tape decks may be connected to the system. Magnetic drums are not fitted to the 7070.

The next large transistor computer system to be announced by IBM was the 7090. This is a general-purpose computer and is the most powerful machine being produced in quantity by IBM. It costs from £880,000 and can perform calculations at five times the speed of the 709. A magnetic-core store is provided that can hold 32,000 computer words of 36 bits each. All other data are stored on magnetic tape. No provision is made for magnetic drums. An important feature of the 7090 is a new unit called a "multiplexor." This controls and co-ordinates the transfer of all information within the data processing system. Up to eight separate data transmission channels may be associated with the multiplexor with the result that as many as eight input-output devices may be operated while the central data processing unit is performing a calculation. From one to ten magnetic tape units, plus a punched-card reader, a card punch and a printer, may be connected to each data transmission channel.

Two types of magnetic tape unit can be used with a 7090 system. Data are read or recorded at 15,000 or 42,000 characters a second by the slower unit and at 62,500 characters a second by the faster. Both high- and low-speed tape units may be included in the same system. Thus, if eight high-speed tape units are operated simultaneously, data are being handled at the prodigious rate of 500,000 characters a second.

Although the 7090 is more powerful than the 709, it costs less to install and operate.

From the foregoing it is evident that the 7090 is a very large machine but because data are handled within the computer in binary form it is more suitable for scientific calculations than commercial work. Consequently, to meet the needs of the user who requires a computer mainly for commercial purposes the IBM 7080 — another large transistor machine — was recently introduced.

In some respects it represents a reversal, once again, in the trend of design because, although it is a large machine, it is described as a com-

The first large transistor computer introduced by IBM was the 7070

mercial rather than a general-purpose data processing system. It is a fast machine and data are handled in decimal binary coded form. Programmes written for the 705 Models 1 and 2 can be run on the 7080 and completed in one tenth of the time, or a programme prepared for the fastest 705—the Model 3—can be performed in one sixth of the time. The 7080 is provided with a more extensive order code than the 705—15 new instructions are included. Also, two independent programmes can be performed concurrently.

Up to 160,000 characters can be held in the main store. As with the other large IBM computers, several auxiliary units may be operated together. Five magnetic tape units may be working simultaneously and up to 50 magnetic tape units may be included in a system.

A 7080 installation is 30 per cent smaller than the equivalent 705 system and requires only 50 per cent of the power. Costs range from £880,000 upward.

Small transistor computers

Smaller computers designed to take advantage of the properties of the transistor are also being built. One is the IBM 1401. It is a commercial machine designed primarily to meet the needs of the smaller business, for the 650, although a medium-sized computer, is still too large for many firms, and it possesses features that are rarely used in commercial work. This does not mean to say that the 1401 is a slow machine. It is an entirely new data processing system and, when it was being designed, advantage was taken of all the improvements made in punched-card machines as well as computers. For instance, data input and output handling speeds have been increased; punched cards are read at 800 a minute and results are printed at 600 lines a minute or punched into cards at 250 a minute.

Cards are read and punched by the same data input-output unit. It is fitted with five output magazines, or stackers, two for the reader and two for the punch. The fifth stacker can be assigned to either, as required. Therefore, after the cards have been read or punched, they can be separated into two or three categories. This limited sorting facility is useful because it eliminates one punched-card operation. For instance, immediately after a mixed pack of cards has been read, the master cards can be separated from the detail cards.

The higher printing speeds have been obtained by employing a new method of printing. A flexible, continuous chain of engraved type faces, rather like a bicycle chain, moves across the paper at a speed of 90 inches a second. A series of electronically operated hammers strike the back of the paper at the appropriate instant, pushing it against the type which prints the character.

The third and last item of the basic 1401 system is the data processing unit which contains the adding and subtracting circuits. As with conventional computers, operations are controlled by a stored programme.

A magnetic-core information store is provided and all data are handled in alphanumeric form. Data and instructions can be recorded in computer words of variable length.

To this basic system may be added a multiplication and division unit and as many as six magnetic tape decks. Two types of tape deck can be fitted. The IBM 729 Model 4 tape deck is the faster. Characters are recorded by this unit at a density of 556 to the inch and the tape is read at a speed of 112½ inches per second, giving the extremely high information transfer rate of 62,500 characters a second.

A 1401 system costs about £50,000 in basic form and up to £100,000 when fitted with magnetic tape.

The data input-output speeds of the 1401 are so high that one of the uses found for this equipment is as an off-line data transcription unit for the larger, vastly more expensive, 700 and 7000 Series computers. By using an IBM 1401 for this work it is possible to improve the utilization of the larger machines. Card reading speeds are increased by 60 per cent and printing speeds by 400 per cent.

Small scientific computers

To match the commercial IBM 1401, in 1959, the IBM 1620 was produced for scientific work. Data input and output are on punched paper tape and a large immediate access store of 20,000 digits capacity is provided. A 1620 costs £30,000.

Another small computer, about the size of an office desk, is produced for engineering work. Designed and introduced before the 1620, this machine, the IBM 610, is intended to provide engineers with a calculating machine that is simple to operate.

In the smaller range of computers, scientific and commercial machines are still segregated. Only computers of the size of the 650 and above are designed as dual-purpose machines.

To distinguish between the many computers built, IBM have adopted the following numbering system: the 700 Series are all large valve computers (incidentally, some of the 700 Series machines are partially transistorized) and the 7000 Series are equally large transistor machines. Calculators and small computers are given numbers in the first half of the 600 range, and medium-sized computers are numbered from 650 upward.

This then has been the mainstream of IBM computer development up to the present day, but the needs of commerce are insatiable. While what might be termed conventional computers were being developed, IBM engineers were looking for a means of storing large quantities of data to which random access could be obtained. This is an essential requirement in many commercial jobs. Extensive records are kept, but in many cases the sequence in which reference will be made to them is unknown.

Ramac

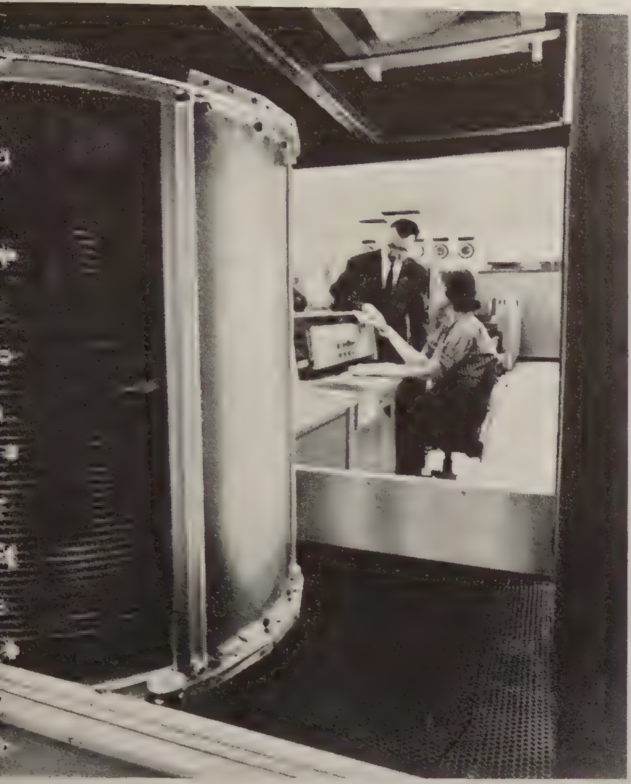
To meet this requirement, in 1955 development was begun on a computer known as the Ramac 305. Ramac stands for "Random Access Memory Accounting Computer." Information is recorded and stored on large metal discs, resembling gramophone records, which are located one above the other on a common spindle. Each disc is two feet in diameter and 50 discs are mounted on a spindle. The discs rotate at 1,200 r.p.m. and data are recorded as a sequence of magnetized spots on the surface of each disc. Arms fitted with electro-magnetic reading and writing heads can be moved quickly to the required track of the appropriate disc. By this means, rapid access is obtained to any of the 5 million to 20 million characters held in the Ramac computer store.

Ramac is used in the following way. As business transactions are completed, the data held on file are up-dated immediately by feeding into the machine a punched card containing all the details of the transaction. For example, if an order is received, the following records are altered at once: the warehouse stock level; daily sales total; customer's account and salesman's record. In addition, the invoice is printed.

This method of working is often referred to as in-line accounting, to distinguish it from the method of accumulating sales information throughout the course of a day, sorting it into order and posting the whole lot in one operation. This latter technique is used with conventional computers. Of course, the nature of the work performed will determine which is the better approach to adopt.

A magnetic-core store of 100 characters capacity and a magnetic drum, on which the programme is stored, are also fitted to the 305

The IBM 305 *Ramac computer. As the name indicates, random access can be obtained to data stored in the machine*



Magnetic discs of a Ramac information storage unit

Ramac computer. All the normal arithmetical operations can be performed by the machine, in fact in all other respects it is a conventional computer. Provision is made for the operator to interrogate the store and have printed out any information recorded on the discs.

Input data are read from either punched paper tape or punched cards. Output data are punched into cards or printed. A Ramac 305 costs from £65,000 upward. An interesting point is that Ramac computers come closer to performing commercial work in the manner of a human clerk than any other data processing machine yet built.

As has already been mentioned, Ramac information storage units may also be fitted as additional items to the IBM 650 or any of the 7000 Series computers.

Even after the development of Ramac, however, there were still many commercial jobs that could not be tackled efficiently by computers, conventional or otherwise, and as a result some additional highly specialized systems have been designed. One of these is the IBM 9090 seat reservation system for airlines. Seat reservation is one of the major problems of the air transport industry. Bookings and inquiries are received from many hundreds of agents located all over a country. All this information must be accurately co-ordinated if revenue or goodwill is not to be lost by the under- or over-booking of flights. To overcome this problem IBM are building for American Airlines a centralized electronic seat reservation and recording system. Every procedure connected with the inquiry, sale, confirmation and control of airline seat reservations will be dealt with by the system.

Two large IBM transistorized computers to be situated at the headquarters of American Airlines in New York will be connected directly by landlines with 1,100 booking offices throughout the United States. Information about seats available, those reserved, and flight numbers will be recorded and stored on magnetic discs within the computer system. Random access can be obtained to any of these data.

When a customer wishes to make a reservation the agent selects a card listing the information about the required route and inserts it into a special desk set. He then presses buttons to indicate the number of seats requested and the date on which the journey is to be made. All this information is transmitted to the computing system in New York. After consulting the records on the magnetic discs, the computer relays an answer back and the flights available are indicated by lights on the desk set. After the customer has made his choice, the agent presses a "sell" button and the data recorded on the information storage discs are amended. At the same time, full details of the flight are printed out in the agent's office and handed to the customer. If, at a later date, the customer wishes to alter his booking, any agent is able to do this no matter where the original reservation was made.

It is expected that each day the American Airlines system will have to make 40,000 reservations, quote 30,000 fares and issue 20,000 tickets. American Airlines already have some experience of electronic seat-reservation procedures as for some years they have operated a local system at La Guardia Airport. In this system all the details of seats available are recorded and stored on a large magnetic drum.

Another commercial problem that has caused business machine manufacturers some trouble and has not yet been satisfactorily solved is the clearing of bank cheques. To help with this work, IBM produced a machine called the 1210 Sorter-Reader. The problem is, of course, that

Year	Computer	Size and type	Typical addition time (seconds)	Price range	Remarks
1948	Selective Sequence Electronic Calculator	Special	0·000286	—	One built at a cost of £330,000. Withdrawn in 1953 after 5 years' service.
1950	Tape Processing Machine	Experimental commercial	—	—	Designed for business applications. Prototype built. Equipped with magnetic tape and magnetic drums.
1953	IBM 701	Large scientific	0·0000625	Out of production	Can perform "floating point" calculations. 19 built.
1954	IBM 702	Large commercial	0·00025	Out of production	First commercial computer to be manufactured by IBM.
1955	IBM 650	Medium general-purpose	0·0008	£70,000 to £290,000	Most widely used computer in the world. Available with Ramac storage
1956	IBM 704	Large scientific	0·000024	£300,000 to £1,000,000	Magnetic-core store fitted. Data can be handled in binary or decimal form.
1956	IBM 705 Model 1 and 2	Large commercial	0·000116		Alphanumeric data handled in 6-bit coded form.
1957	IBM 705 Model 3	Large commercial	0·000088		Equipped with data synchronizers that permit several auxiliary units to be operated simultaneously.
1957	IBM 709	Large general-purpose	0·000024		First large-scale computer built by IBM that was suitable for both scientific and commercial work.
1957	IBM 305 Ramac	Small commercial	0·03	£65,000 to £200,000	Random access can be obtained to data recorded on magnetic discs.
1958	IBM 7070	Large general-purpose	0·000072	From £200,000	First large transistor machine to be announced by IBM.
1958	IBM 610	Small scientific	0·28	£21,600	Desk-size computer for engineers. Easy to operate.
1959	IBM 7090	Large general-purpose	0·0000048	From £880,000	Largest computer system for general use being manufactured by IBM.
1959	IBM 1401	Small commercial	0·00031	£50,000 to £100,000	May be used as an off-line transcription unit for Series 700 and 7000 machines.
1959	IBM 1620	Small scientific	0·00056	£30,000	Small transistor computer. Data input and output on punched paper tape.
1960	IBM 7080	Large commercial	0·000012	From £880,000	Can perform programmes written for the IBM 705 in from one-sixth to one-tenth the time.

certain information on a cheque must be legible to both men and machines. One method of achieving this is to print rather oddly shaped though legible characters on the cheque in magnetic ink. The printed outlines can be read visually and the machine can magnetically sense and identify the same printed shapes.

Customers' account numbers are printed in magnetic ink on the cheques before they are issued. When a cheque is received back at the bank for payment the amount is transcribed and imprinted on it, also in magnetic ink. Of course, the signature that gives the document its authority has to be identified. As this is too difficult a task for a machine, each cheque must be visually inspected, but once the cheque is accepted the remainder of the data processing operations can be carried out by machine.

Mixed batches of cheques of all shapes and sizes are fed into the Sorter-Reader, which reads the imprinted data and sorts them into order. Alternatively, the machine can be connected to a computer to provide the necessary input data direct.

In addition to the enormous amount of work that IBM have expended on the development and construction of digital computers for scientific and commercial purposes, time has been found to build specialized computers for the United States armed forces. One of the most famous of these is Norc (Naval Ordnance Research Calculator) because when it first went into operation, in 1951, it was claimed to be the fastest in the world. In this rapidly developing field, however, such claims do not survive long.

Another military computer built by IBM is Sage (Semi-Automatic Ground Environment). Information obtained from a radar warning ring is used to calculate the height, course and speed of approaching aircraft. The computer also directs guided weapons and fighter aircraft to intercept the attackers. Forty Sage computers have been built at a cost of £3½ million apiece.

IBM also manufactured an airborne computer called Brane (Bombing Radar Navigation Equipment). It is carried in the B-52 Bombers of the United States Strategic Air Force.

Stretch

Finally, there is Stretch, a computer built for the United States Atomic Energy Commission and a second larger version of this machine is scheduled to be completed later this year. Both are transistor computers and some idea of their immense size can be obtained from the area they cover. Despite the compact construction that can be obtained with transistors, the smaller Stretch occupies 2,000 square feet of floor space and the larger version, 4,000 square feet. An information store of 100 million computer words is to be provided. The smaller Stretch occupies the same floor space as an IBM 704 and is 125 times faster.

The reason such large and complex computers are required is that in nuclear physics as many as 100,000 million arithmetical operations may have to be performed in order to obtain one result. For problems of this magnitude even the IBM 7090 is too slow.

Other types of problem for which very fast computers are necessary if a solution is to be obtained in a reasonable time are those solved by the mathematical techniques of linear programming and the Monte Carlo method. How these techniques work and how they may be used has already been described in *Data Processing*.* Commercial problems to be solved by linear programming can be quite as complex as any of those encountered in science.

Thus, in the short space of ten years IBM have progressed from the initial decision to start on the intensive development of large-scale computers to the completion and operation of Stretch. During those ten years, nine large computer systems and five small-to-medium-sized computers have been designed, developed and put into production. In addition, several special-purpose data processing systems have been built for commercial and also for military use.

After this tremendous engineering effort it might be thought that the pace will slacken. However, there is no indication that this will be so; in fact, it seems more likely that progress will be faster. In the last ten years, two methods of storing data—the electrostatic tube and the mercury delay line—have been invented, developed and abandoned in favour of the new and faster device—the magnetic core. Transistors are also replacing valves.

In the next ten years new storage devices such as thin magnetic films and super conductive films held at extremely low temperatures will be introduced. With their use it is confidently expected that more information will be stored in less space at less cost. New computing elements are also being developed. The parametric oscillator can handle digits at one hundred to one thousand times the speed of present-day computing circuits.

From this it can be gathered that engineering development is rapidly outpacing the application of computers to industrial and commercial work. The big problem in the commercial world is that, at present, we do not know how to use effectively the computers already in existence, much less the new ones that are on the way. Contrary to popular belief, the data processing problems of commerce are far more varied and complex than science, largely because they have not been reduced to logical mathematical form. Surely the major aim of business users now must be to develop new systems of administrative control that can utilize the enormous capabilities of these new machines?

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*See "Two scientific-management techniques—the Monte Carlo method and linear programming," *Data Processing*, January-March, 1960.

An operator makes an average of 1,000 *entries an hour*

Analysing business data

Logabax Limited market a range of keyboard accounting machines equipped with 198 totalling registers. Data entered on the keyboard are printed and simultaneously entered in the appropriate registers of the machine. In this way, statistical totals are compiled at the same time as the normal business documents are produced.

Either positive or negative values may be recorded, and the capacity of each register ranges from + £60,000 million to − £30,000 million. Data can be transferred from one register to another when progressive or grand totals are required. A record of all entries made is printed on a tally roll. The results of an analysis are also printed on the same roll.

A recent development is the construction of a Telebax machine which is similar to a Logabax machine except that it is operated automatically by 5-channel punched paper tape. With this machine the results of an analysis may be punched in paper tape as well as printed. Logabax machines cost from £3,600 to £4,500 and Telebax machines from £10,000 to £15,000

ALTHOUGH statistics are the raw material of business decisions, managers are frequently deterred from asking for more detailed analyses because they know, or fear, the high cost of obtaining them. To some extent this problem can be avoided if use is made of machines specially designed for statistical work. Logabax Limited—the British subsidiary of a French company—import into Great Britain a range of analytical accounting machines built by the parent company in Paris.

In appearance, these machines resemble conventional keyboard accounting machines. The major difference is that they are equipped with at least 198 separate registers in which totals can be compiled. Each register can record sterling values up to £60,000 million positive or £30,000 million negative. Actually one penny less than the amounts quoted.

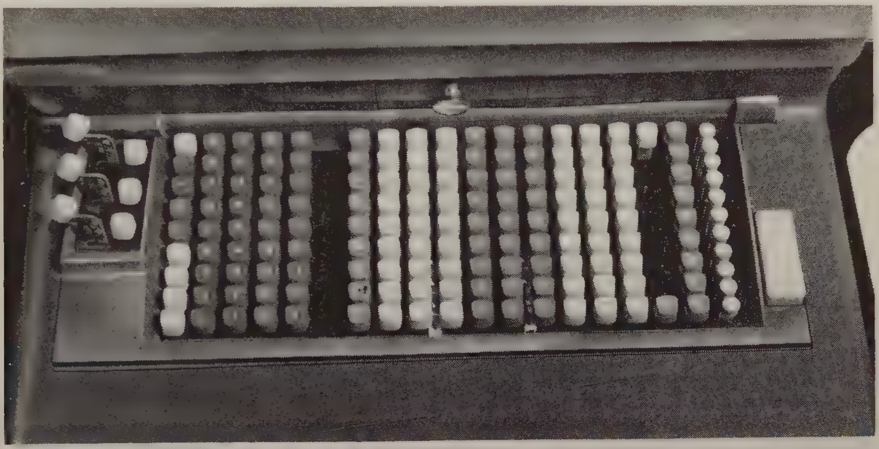
A feature which distinguishes these machines from others used for statistical work is that data are entered and sorted to the correct heading in one operation. Normally, data are first recorded, then sorted and, finally, totalled—three separate operations.

Many different Logabax machines are built but all have been developed from one basic design. This consists of a numerical keyboard, a printing unit and the 198 mechanical registers already mentioned. The registers are grouped in two banks of 99.

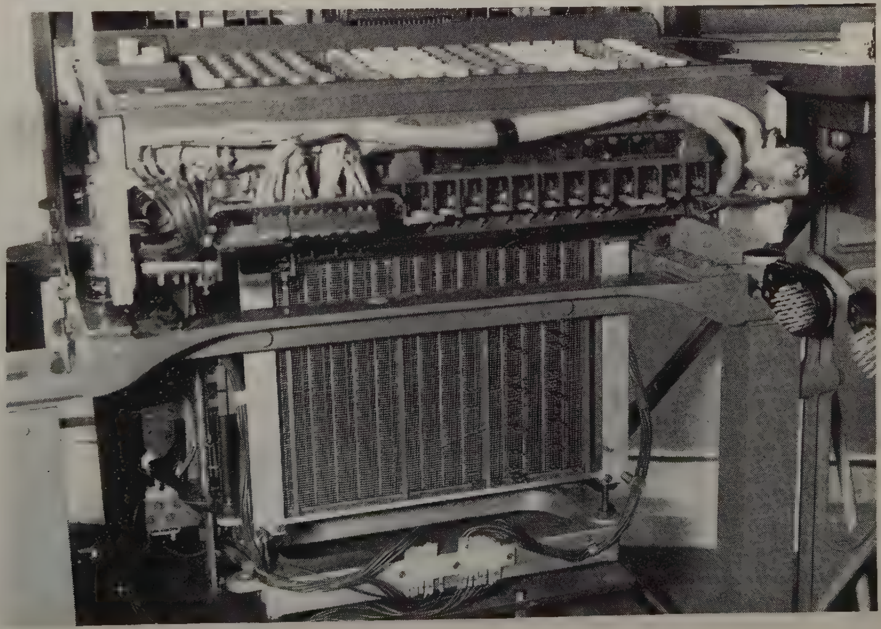
All data entered on the keyboard are printed on a tally roll, or, maybe, a ledger card and at the same time are entered into the appropriate registers. As the accounts are up-dated so the data are analysed under different headings.

Logabax machines may be equipped with either sterling or decimal keyboards. A sterling keyboard consists of 13 columns of keys. One column, the pence column, contains 11 keys, the next column nine keys for the unit shillings, there is one key in the tens-of-shillings column and nine keys in each of the remaining columns. All these keys are arranged on the right of the keyboard. On the left are two further groups of keys. One contains five columns of keys and the other, on the extreme left, comprises six keys.

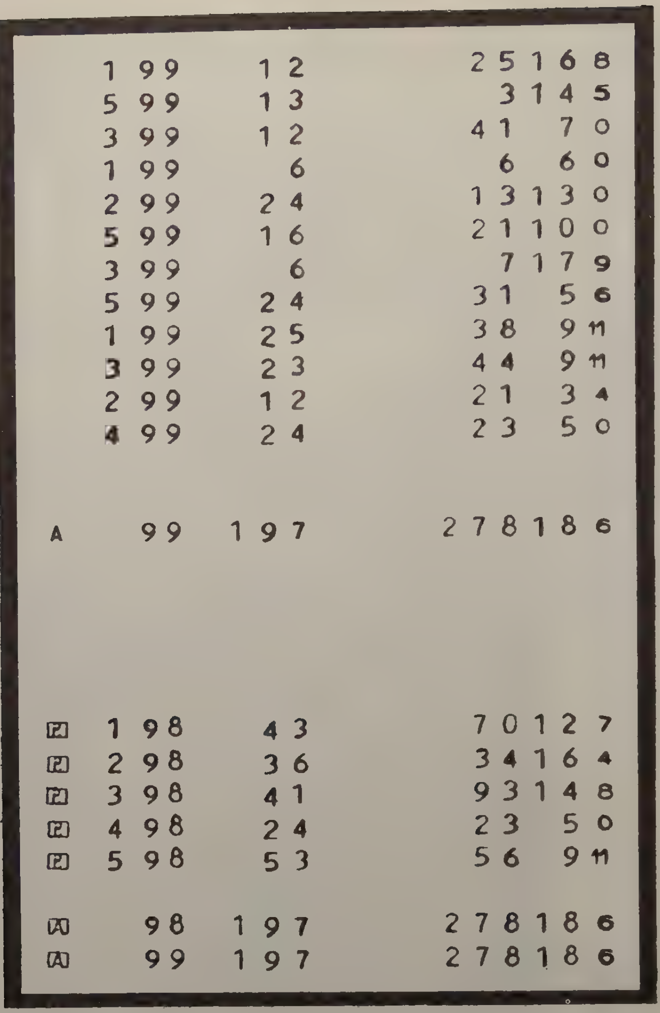
One column of keys in the first group controls the operation of the machine—that is, whether the value entered on the keyboard is to be added



Sterling keyboard fitted to a Logabax machine



Beneath the keyboard are the banks of mechanical registers



```
    1 99    1 2      2 5 1 6 8
    5 99    1 3        3 1 4 5
    3 99    1 2      4 1   7 0
    1 99      6        6   6 0
    2 99    2 4      1 3 1 3 0
    5 99    1 6      2 1 1 0 0
    3 99      6        7 1 7 9
    5 99    2 4      3 1   5 6
    1 99    2 5      3 8   9 11
    3 99    2 3      4 4   9 11
    2 99    1 2      2 1   3 4
    4 99    2 4      2 3   5 0


A     99  1 9 7    2 7 8 1 8 6



🅉   1 98    4 3      7 0 1 2 7
🅉   2 98    3 6      3 4 1 6 4
🅉   3 98    4 1      9 3 1 4 8
🅉   4 98    2 4      2 3   5 0
🅉   5 98    5 3      5 6   9 11

🄰     98  1 9 7    2 7 8 1 8 6
🄰     99  1 9 7    2 7 8 1 8 6
```

Portion of a printed tally roll. The first line indicates that the value £25 16s 8d, printed on the right, has been entered into blue register number 1 and red register number 99. The quantity of items ordered—12—is printed in the middle column

or subtracted or whether the total already held in a register is to be printed out as a sub-total or a grand total or transferred to another register. When a total is printed the register is cleared. When a sub-total is printed the numerical value is retained in the register. The remaining four columns of keys in this group are divided into two sets, one coloured blue, the other red—one set for each bank of 99 registers. By depressing one pair of keys in each bank, the operator selects the registers which are to receive the data entered on the keyboard.

Three of the six remaining keys in the small group on the extreme left of the keyboard are "repeat" keys. If a "repeat" key is depressed, it locks a section of the keyboard and the information entered there is retained and subsequently repeated. The other three keys perform the reverse function and clear the keyboard of data entered on it.

To make an entry, the operator first clears the keyboard. She then sets the data on the main keyboard by depressing the appropriate keys, which remain down. These data might be the total value of an invoice or the value and quantity of one product appearing on an invoice. Then the operator selects the registers into which these data are to be entered. One blue register and one red register can be selected. It is not possible to enter data into two registers of the same colour simultaneously, although it is possible to transfer data between registers—more will be said about this later. Having set the register keys and the amount keys, the operator next presses a "control" key according to whether the amount is to be added or subtracted from the totals already recorded in the registers. Lastly, the "motor" bar is pressed.

Immediately, the value set on the keyboard is entered into the registers and printed on the tally roll. After the operation has been completed, all the keys are returned to their normal raised positions unless one of the repeat keys is down. Everything is now ready for the next entry.

Proceeding in this way, an operator can make an average of 1,000 entries an hour.

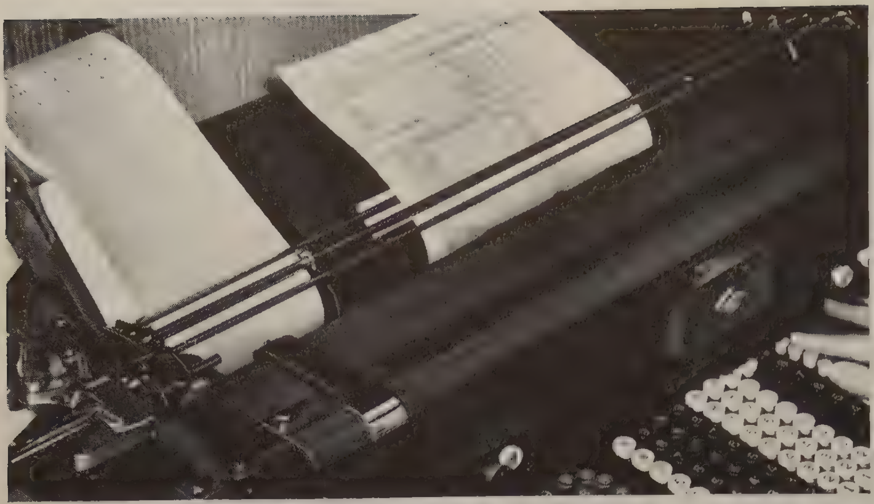
Printing totals

Once the work of entering all the data has been completed, the totals recorded in the various registers can be printed out. To do this, the operator merely depresses the two keys which identify the register and a control key. When the motor bar is pressed, the value in the register is printed on the tally roll. In a similar manner it is also possible to transfer totals from one register to another. The appropriate register keys are depressed, plus a control key. As the transfer takes place, the total is simultaneously printed on the tally roll for record purposes together with the code numbers of the registers. Data can only be transferred between two registers in different banks, from blue to red or vice versa. If it is necessary to transfer a total from one blue register to another blue register, two operations are needed—first from blue to red then from red to blue.

So much for the handling of numbers within the machine, what about printing? If the machine is used solely for analysis work, it is equipped with a tally roll printing unit. The printed record provides a means of checking the accuracy of the data entered on the keyboard and also the operations carried out.

Where the machine performs a dual function, such as statistical analysis and up-dating account ledger cards, it is equipped with a moving carriage similar to an orthodox accounting machine and it can, in fact, be used as a conventional accounting machine. An account ledger card is fed into the machine and the existing balance is picked-up and printed in the appropriate column of the card in the usual way. Simultaneously, the data are entered in two of the registers of the machine. The carriage then moves the ledger card automatically to the next column and a new debit or credit entry is made. These data are also sent to the two chosen registers. Then the carriage moves the document to the column in which the new balance is to appear and this value is obtained from one of the registers and printed in the correct position. Thus at the end of a posting run, not only will

A Logabax accounting machine equipped with a moving carriage. A ledger card is being up-dated



Where the machine is provided with a split platen, two documents can be prepared side by side

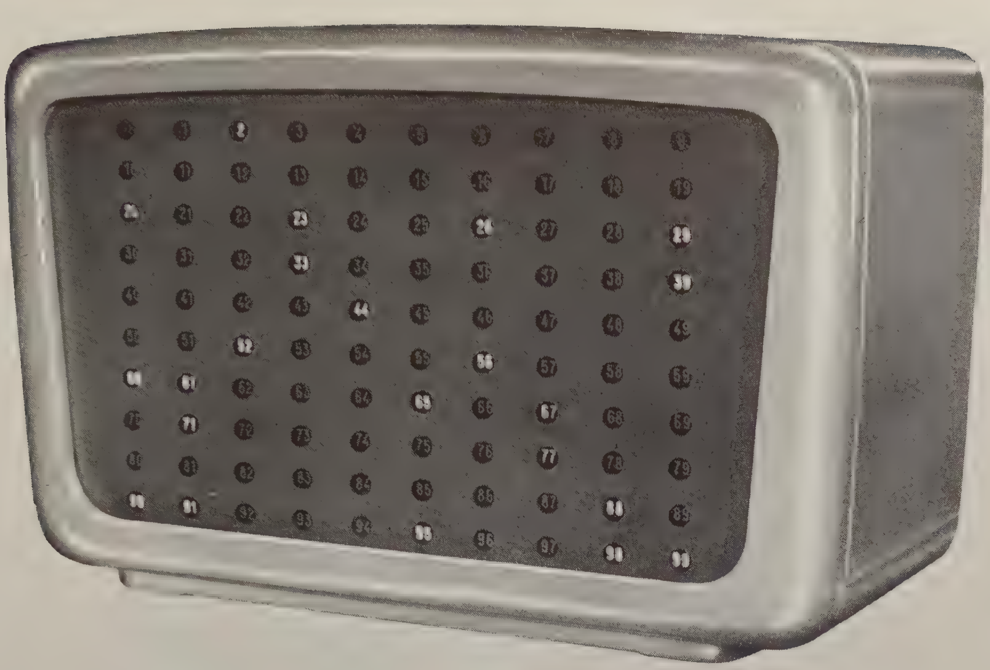
Setting small switches enables the keyboard to be divided, thus permitting both quantity and value to be entered

all the ledger cards have been up-dated, but also certain statistics will have been compiled in the secondary registers and, what is more important, these figures will be available immediately.

All machines equipped with moving carriages are fitted with control bars to initiate certain actions automatically. For example, after the existing balance and the new credit or debit entry have been made, the action of printing the new balance is initiated automatically by the control bar as the carriage moves the ledger card or other document into position.

If the machine is equipped with a split carriage, that is, the printing platen is divided in two, both a ledger card and a tally roll can be prepared. In fact, any two documents that fit within the widths of the separate platens can be handled.

It is also possible to divide the main keyboard in two, so that both quantity and value can be entered and analysed. As there are ten keys for recording £ units, provided the value of the largest entry leaves sufficient columns of keys available for the quantity, this is a perfectly feasible and straightforward procedure.



Whenever a register contains a total, the register's number is illuminated on the display unit. A second display unit can be connected to the second bank of 99 *registers*

Internal switches are pre-set and data entered on one side of the keyboard are sent to one half of the selected register while data on the other side are entered in the other half of the same register. Care is required to ensure that the value compiled in the right-hand half of the register does not "carry over" into the left-hand half.

Analysis of sales

Many different jobs can be performed on these machines. A typical one is the analysis of sales. An operator is given copies of invoices sent out during the day. Usually, separate figures are required for each sales area, so the first job is to sort the invoices into batches. Taking each invoice of a batch in turn, the operator enters on the keyboard the cash value of the first item on the invoice. These data are sent to two registers—one blue, one red. In the blue register the total value of the invoice is compiled. The red register selected will depend on the goods supplied. One red register is allocated for each item in the range of goods sold by the firm. For convenience, each product is given a sales code number between 1 and 99 to correspond with the range of register numbers available. Then all the operator has to do is select the red register keys which correspond to the product's sales code number and the value is entered in the appropriate register.

By comparing the data printed on the tally roll with that on the invoice the operator can confirm that she has performed the transcription correctly. When all the items for one invoice have been dealt with, the total value of the order can be obtained from the blue register and printed on the tally roll. This total is compared with that on the invoice. This provides a second check on the accuracy of the transcription. When the invoice total is printed, it is simultaneously transferred to a red register where the grand total for the sales area is being compiled. In this way, detailed sales statistics by product and by area are obtained quickly.

The example just given is relatively simple and is performed by one operator. However, in those cases where absolute accuracy is important, a third method of checking is used. A comparison is made between transcriptions performed by two operators. First, one of the operators enters all the data in the machine and produces the normal printed records and sales analysis totals. Next a second operator, using the same machine and the same documents, repeats the transcription, but this time all items are entered as negative quantities. At the end of this sequence, the totals in each register are printed out. If the two transcriptions agree, then each register should contain zero because, of course, the positive total compiled in the first sequence will be reduced to zero in the second.

Normally, for statistical work, exact figures are not required and it has been found that the average operator only makes errors that affect the final totals by one or two per cent. Consequently, for most applications, elaborate checks of the type described are not necessary because they cost more than they are worth.

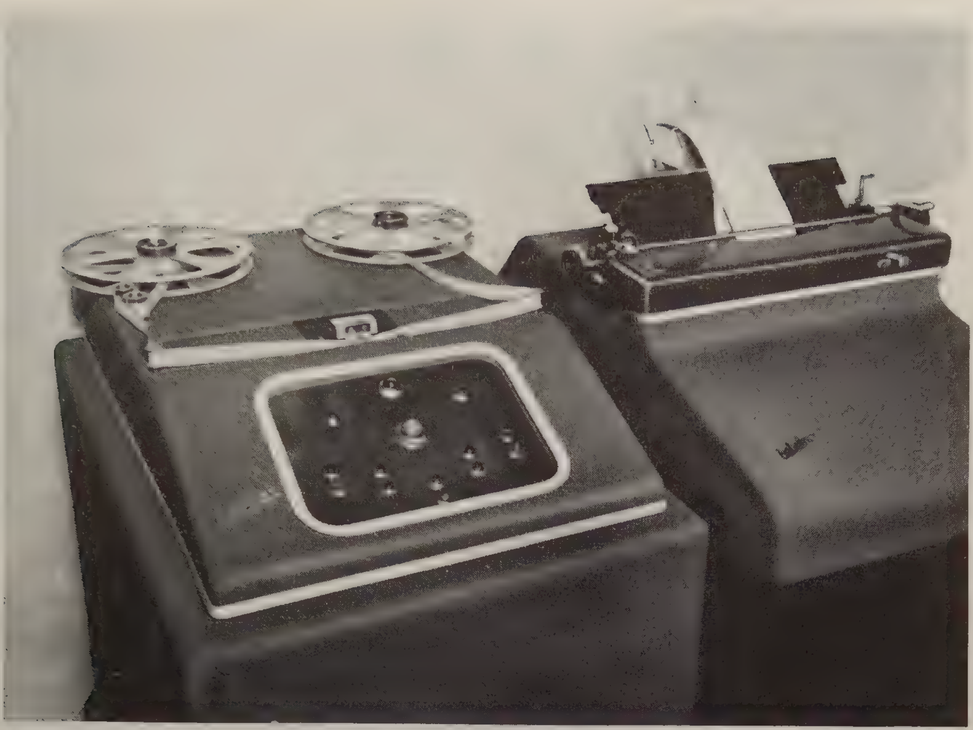
Obviously, more complicated analyses of sales data than that described are possible. Also, work such as stock control, up-dating ledger accounts, costing and many jobs of this nature can be performed.

To increase the versatility of Logabax machines, various accessories have been built. One of these is an illuminated panel, similar to a television screen. Numbers from 1 to 99 are engraved on this panel, one for each of the 99 registers in a bank. Each number can be illuminated separately. When this device is connected to a machine, the numbers of all registers containing totals are illuminated. This indication is useful when a large and complicated analysis has been completed and the operator wishes to print out the results. Unless some indication is given of the registers containing totals, the operator may have to print out the contents of each of the 99 registers in turn, whether they contain a total or not, just to be certain of obtaining all the figures. Obviously, when a display screen is fitted, this is unnecessary—only the registers indicated need be selected. A second display unit can be fitted to the other bank of 99 registers if this is required.

Third bank of registers

It will be remembered that data can be entered into two registers simultaneously—one register in each of the two banks. Needless to say, there are applications where it is advantageous to enter the data into a third register. For such work, Logabax build machines equipped with a third bank. Nine registers are included in this bank and the selection keys are coloured green to distinguish them from the red and blue keys of the other two banks.

A Logabax machine joined to an electric typewriter. The carriage is free to move from one machine to the other



A Telebax machine is similar to a Logabax except that it is operated automatically by 5-channel punched paper tape. Entries are made at the rate of approximately 2,400 an hour

These registers operate exactly as the others and totals can be transferred between any three registers in the manner already mentioned.

The machines described handle numerical data. In many applications, alphabetical information has to be typed in addition to figures. For work of this nature, another version of the Logabax machine is built. It comprises a Logabax Model 200 and an electric typewriter placed side by side. Rails connect the two machines, and the carriage holding the documents is free to move from one machine to the other.

Telebax

Yet another development is the Telebax. This is a Logabax machine operated entirely automatically by punched paper tape.

All data to be analysed are first recorded in 5-channel paper tape. This tape may be produced as a byproduct of some other operation, such as the recording of a sale at a cash register.* As the punched tape passes through the Telebax machine, data read from it are entered into the appropriate registers automatically. A printed record is produced of all the entries and the registers used. Because the data are handled automatically, the speed of operation is higher than for a manual machine. Entries are made at the rate of approximately 2,400 an hour.

In addition to a tape reader the Telebax machine is equipped with a tape punch. Selected data obtained from the input tape can be punched directly into the output tape without being recorded in the machine. In this way data not wanted for the first analysis can be sorted out and recorded in a second tape for analysis at a later date. Alternatively, the results of an analysis can be punched in tape.

Logabax machines cost from £3,600 to £4,500 and Telebax machines from £10,000 to £15,000.

For firms that do not have sufficient statistical analysis work to keep one machine fully employed the Logabax Company have established service centres at their offices throughout Great Britain. A charge is made of 30 shillings per 1,000 entries.

At present there are over 120 Logabax installations in Great Britain and the majority of these (over 90 per cent) are engaged on the preparation of sales statistics.

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*See "Recording data at the point of sale," *Data Processing*, January-March, 1960.

Cards are punched at the rate of 400 *an hour or read at* 4,000 *an hour*

Edge-punched card tabulator

Data can now be recorded as punched holes in the central area of a conventional edge-punched card and handled automatically by a new kind of machine—the edge-punched card tabulator. The machine reads the information recorded in the cards and prints it on a tally roll. Totals are compiled automatically and the results are printed on the tally roll or punched in a summary card for record purposes. This machine extends the range of work for which edge-punched cards can be used. It costs £1,350

WITH the object of spanning the gap between manual and machine punched-card data processing systems Royal McBee have recently introduced a tabulator which operates with edge-punched cards. Normally, all the data on an edge-punched card are recorded by a series of notches clipped in the four edges. Generally the same data are also typed on the central area of the card. An innovation by Royal McBee is to record additional data as punched holes in this central area, and it is data recorded in this form that can be handled automatically by the new tabulator.

The tabulator performs several functions. First, it punches data into cards. Secondly, it reads data already punched in cards and prints this information on a tally roll. Thirdly, it compiles and prints totals. Fourthly, it may be used as a reproducing punch to produce duplicate copies of existing cards. And lastly, it records, by punching, totals in summary cards for record purposes. The machine costs £1,350 or it may be rented for £40 per month.

It is envisaged that this special form of edge-punched card will be used in the following way. Cards will first be selected or sorted in some desired order using conventional manual edge-punched card techniques.* Then, the cards will be passed through the tabulator, one at a time, for printed lists to be prepared, totals compiled and for summarized figures to be recorded in summary cards. Summary cards are, of course, held on file and carried forward to other data processing operations. Used in this way, the tabulator extends the range of work for which edge-punched cards are applicable.

Data to be handled in this fashion are recorded as a pattern of very small punched holes ($\frac{1}{16}$ inch in diameter) in two local areas near each corner of the card. Only one numerical value is recorded in each area. Consequently, each card contains up to eight recordings (two numbers in each of four corners). A typical card is shown in the accompanying illustration.

Values attributed to each hole depend upon the position it occupies within the recording area. Each area measures 1·2 inches wide by 0·7 inch deep and is divided into 12 vertical columns and four horizontal rows. Ten columns are available for the number, one column is used for code holes that control the action of the tabulator and the remaining column is for a carry digit. As each column represents one decimal figure numbers containing up to ten decimal digits can be recorded.

Holes are punched in each column in any of four vertical positions, or rows. A hole punched in the top row represents 1, in the second row 2, in the third row 4, and in the fourth row 7. By punching one or, at the most, two holes in a column any decimal digit from 1 to 9 can be represented.

Construction of tabulator

The tabulator consists of a steel desk unit with a central keyboard on which the numerical data are entered. Above this is a small tally roll printing unit. Below the keyboard are two card tracks along which cards pass from left to right. Data are punched into cards proceeding along the lower track and are read from cards passing along the upper track.

To record data in edge-punched cards the machine is operated in the following manner. Normally the data to be entered in the card are already typed on it, in the central area. A pack of prepared cards is given to the machine operator who reads the required data from the cards, one at a time. She depresses the appro-

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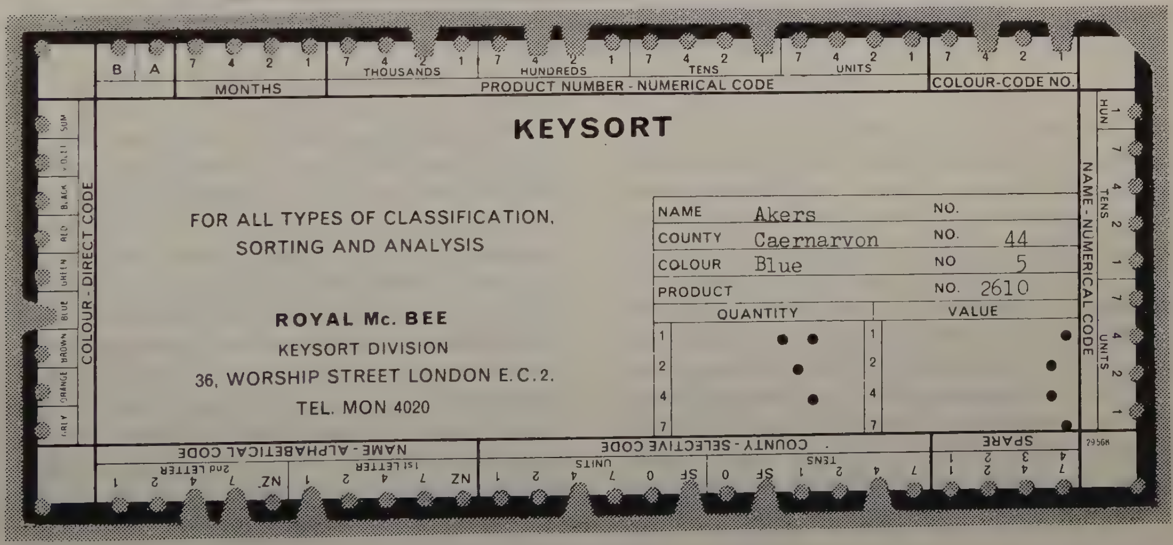
* See "Edge-punched cards," *Data Processing*, July-September, 1959.

Numerical values 12,500 *and* 68, *representing quantity and value respectively, recorded in the lower right-hand corner of an otherwise conventional edge-punched card*



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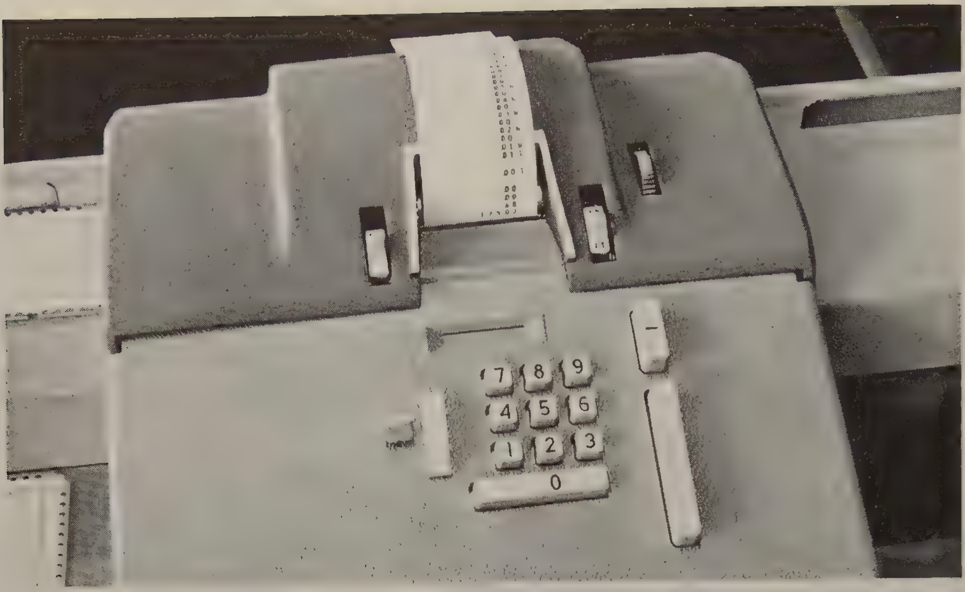
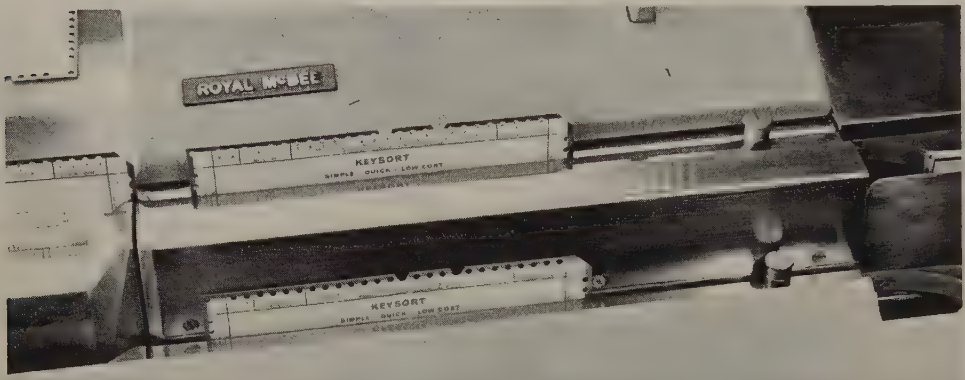


A printed record is kept of all information that is either read from a card or entered on the keyboard



Information is read from cards passing along the upper track and data are punched in cards proceeding along the lower track. The two knobs which control the positioning of the cards are on the right

priate buttons on the keyboard and places the card in the input hopper on the left of the lower card track. The card passes immediately from the hopper along the track and comes to rest at a position below the keyboard where the punch is located. When the "enter" button is pressed, the numerical data set on the keyboard are punched into the lower right-hand corner of the card which is then ejected into the output hopper. At the same time the data are also printed on the tally roll which can be examined to check the accuracy of the transcription operation. In this manner an operator prepares cards at a speed of approximately 400 an hour.

When data recorded in cards are to be printed, they are passed along the reading track of the machine. Approximately 4,000 cards an hour can be handled. The reading track is situated immediately above the punching track. Cards placed in the hopper on the left of the track are fed, one at a time, along the track until they arrive at the reading position where they stop. The reading station is immediately below the keyboard. Numerical data read from the card are printed on the tally roll and, if required, are also sent to an adding register. Whether this is done or not depends upon the control hole punched in the twelfth column associated with the number. Absence of a hole in this column indicates that the number is to be added to the total already recorded in the register. A hole in the first row indicates that the value is not to be sent to the register at all, and a hole in the third row indicates that it is to be subtracted from the total in the register.

After a batch of cards has passed along the reading track, a total can be printed on the tally roll by pressing the "total" key. If this information is to be recorded in a summary card a blank card is fed into the lower punching track. When the "total" key is pressed, the value is punched into this card at the same time as it is printed on the tally roll.

Although a ten-digit number is the largest number that can be entered on the tabulator keyboard, the adding register can accommodate 11 decimal digits. When a number of this magnitude is punched into a summary card the eleventh significant digit is recorded in the carry column available in the recording area.

Identical data may be recorded in a series of cards. One way in which this is done is to set a "repeat" switch, and data entered on the keyboard are retained and punched in every card passed along the punching track. Or, the card containing the data to be copied can be fed into the reading track and a blank card placed in the punching track. When the "total" key is pressed, data read from the first card will automatically be reproduced in the second card.

Feeding cards

Although eight, ten-digit numerical values can be recorded in each card, the reading and punching units of the tabulator only operate on one area, or number, at a time. Since these areas are arranged in groups of two near the corners of the card, the way the card is fed into the reading and punching tracks is important. As the cards sit vertically in the tracks, data recorded in either of the two areas located in the bottom right-hand corner are sensed. Which one of these two areas is sensed, or punched, is determined by the setting of a three-position control knob fitted adjacent to each track. If the mark on the knob is turned to the right the card stops so that the right-hand area of the card is positioned under the reading or punching head. Conversely, if the knob is turned to the left, the left-hand area of the card is positioned under the operating head. If the knob is turned so that the mark is vertical, a card passed along the track stops twice: once when the right-hand area is in position and again when the left-hand area is in position. Counters can be fitted next to the output hoppers to record the numbers of cards that travel along each track.

The tabulator successfully handles cards of different thicknesses. In fact, it can read data punched in paper dockets. Also, soiled and crumpled cards, after being roughly flattened, pass through the machine without adversely affecting its operation.

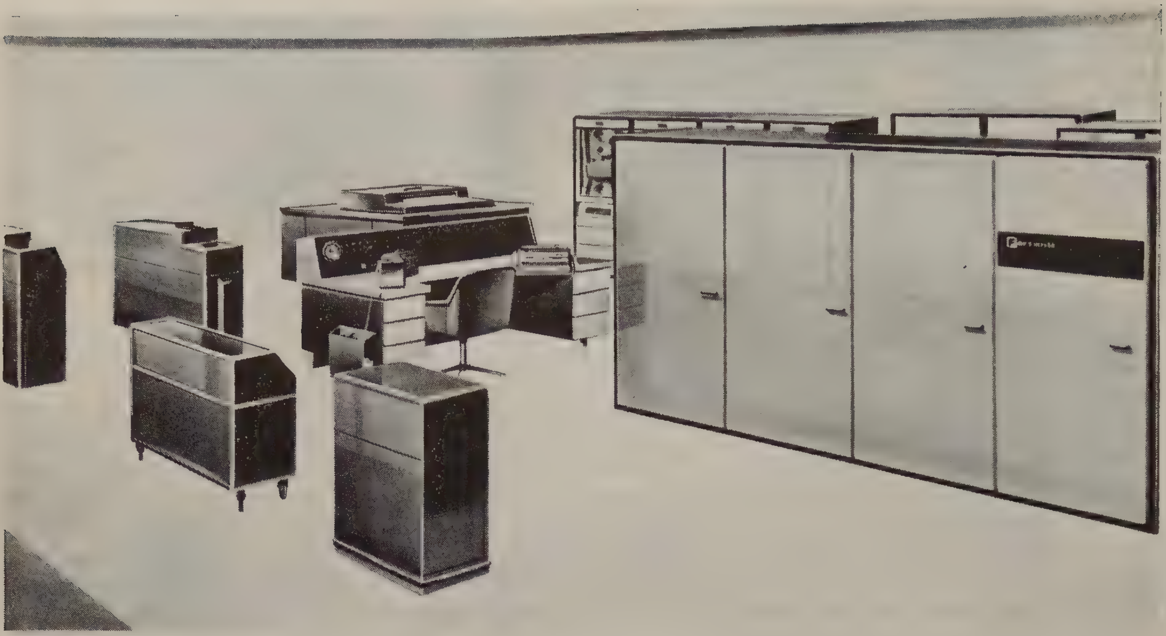
Stock control

As already mentioned, the principal use of the tabulator is to produce printed lists from sequences of cards, prepare totals, and punch summary cards. A typical application for which the tabulator would prove suitable is stock control. Each issue, or receipt, of material is recorded in an edged-punched card. Once a week, say, the cards are sorted into order, together with summary cards containing details of the previous stock position. All the cards dealing with one item are then passed through the tabulator and a list printed of all the issues and receipts made that week. Finally, the stock summary card is passed through and the "total" key pressed. Immediately the number of items left in stock is printed out and, if a blank card is placed in the punching track, a new stock summary card is produced simultaneously. This card is retained on file and carried forward to next week's operation.

At present, only decimal numbers can be added in the register. However, a new unit is being developed so that sterling values can be handled as well.

The headquarters of the Royal McBee organization is in the United States and there the company is developing a number of data processing machines to meet the needs of the commercial and business world. This equipment ranges from manual edge-punched card systems and the tabulator described to electronic digital computers.

A novel development being pursued by Royal McBee is the fitting of an input unit to their small desk-size computer, the LGP-30, that reads data from edge-punched cards of the type described. This is all part of the policy of creating a graduated range of equipment that bridges the gaps in existing data processing equipment. In this way the company intend to be in a position to create installations of any desired capacity and complexity to suit the particular needs of the individual user.



The prototype Orion will be completed this year. This is an artist's sketch of a typical installation

ORION

Ferranti's new time-shared data processing system

Orion is a large "second generation" data processing system that can be used for either technical or commercial work. Several different programmes can be stored in the machine, worked on and completed in little more time than it takes to handle a single programme. This is possible because the design allows the time of the central computer to be shared among many data input-output units so that the maximum performance is obtained from each. The ways in which this new technique known as "time sharing" can be applied are discussed in detail

TRANSISTORS are used throughout Orion, which is a medium-to-large data processing system. It can be employed equally well on technical and commercial work, and it can handle any of the three basic machine documents—punched cards, punched paper tape and magnetic tape. The prototype machine is being constructed at Manchester, England, and is expected to be completed this year. The major advance in design achieved with this machine is that several of its units can be operated at the same time or, to use the technical term, "time-shared," which, briefly, means that the time of the central computer is shared between many programmes and data input-output units.

With the types of computer in general use today, each programme is performed separately and the time taken to complete it is often determined by the speeds of the data input-output units. It was to break free from this limitation that designers evolved the technique of time sharing. A time-shared machine can store several programmes and work on them concurrently, and the time taken to complete one of these programmes is only a little longer than the time that would be taken if it were performed alone.

Time sharing is thus a most valuable procedure because it enables better use to be made of both the computer and the auxiliary equipment, resulting in a reduction in the costs of data processing.

The reason why two or more calculations can be performed concurrently is that the computing circuits of the central computer can handle information much faster than the data input-output units can provide it or record it. To give some idea of the relative speeds, consider the operation of a card-reading unit. It takes 100 milliseconds (0·1 second) to read all the data from a standard 80-column punched card, but the computer converts these data into the binary form in which the data are handled within the machine in 8 milliseconds (0·008 second). The transcription is accomplished in one-twelfth of the time taken to obtain the data. With a time-shared computer, instead of leaving the computing circuits idle for 0·092 second until the next block of data is obtained from the following card, the circuits are switched to work on a second programme. In a similar manner, when the computer is not working on the second programme it is switched back either to the first programme or to yet another one.

In this way it is possible to keep several data input-output units and several different programmes in almost continuous operation. The number of programmes that can be performed concurrently is determined by the number of data input-output units available.

To be able to operate a computer in this manner, a large fast immediate-access store—the working store—is required. For this reason, magnetic cores were chosen as storage elements. A store of 4,096 computer words capacity is provided in Orion and provision has been made for the capacity to be increased up to a maximum of 16,384 words. All information in its passage from one unit to the next goes through this store, and naturally the bigger the store the more time-shared operations that can be performed.

As the magnetic core store is the main traffic centre, the speed with which it can handle data is of fundamental importance. Usually, within the computer data are transferred in words containing 48 bits and a complete word can be passed into or out of the core store in 12 microseconds (0·000012 second).

Obviously some system of priorities must be in force within Orion to regulate the use made by the programmes of the common computer items such as the control and arithmetical units. This is done by a master control programme or, as it is more appropriately called, an "organization" programme. This programme is recorded permanently in a part of the information store that is isolated from the rest. Should it be necessary to alter the organization programme, this can be done by Ferranti engineers, but as far as the computer operator is concerned it is permanently built into the machine.

The organization programme controls the operation of the computer in the following way. Every time the current work is held up because some data have to be transferred, and also every time such a transfer is completed, the organization programme surveys all the stored programmes and decides which one has the highest priority and should be worked on next. Highest priority is given to programmes which at that moment are using mechanical units, such as Xeronic high-speed output printers, which once started cannot be operated intermittently. Next in order of priority are programmes using the slower mechanical devices such as punched-card input-output units. And, finally, the lowest priority is given to programmes using magnetic tape units and to programmes consisting almost entirely of calculations.

Programming

In spite of the fact that several programmes can be performed together, this does not impose any additional burden on the programmer because, as far as he is concerned, each programme is written as a separate entity. He does not have to make any allowance for the possibility that the programme may, or may not, be performed with others. The only difference is that he does not specify the actual addresses in the working store where data are to be held; he quotes relative addresses only. What occurs is that when programmes and data are read into the machine they are stored in the locations available at the time—the computer converts the relative addresses into actual addresses and keeps track of where the various items are stored.

Every programme requires a certain amount of the working store capacity together with certain auxiliary units such as punched-card readers and magnetic-tape decks. These requirements are stated at the beginning of each programme and when this information is entered into the computer it allocates the units required and designates the working store locations to be used. It also "reserves," or isolates, these storage locations and input-output units so that no other programme can possibly interfere with them. In effect, when the computer is engaged on, say, four programmes, it splits itself into four independent sections. Each section comprises a part of the working store and the appropriate data input-output units.

Immediately after a programme has been read into the computer, information about the units allocated is printed out by an electric typewriter—a Flexowriter—at the control desk. This complete operation (reading the programme and printing out the allocations) is called the reservation procedure and a special programme is permanently stored in the machine for this purpose. A record of the auxiliary units allocated to each programme and how far each programme has progressed is maintained by the organization programme.

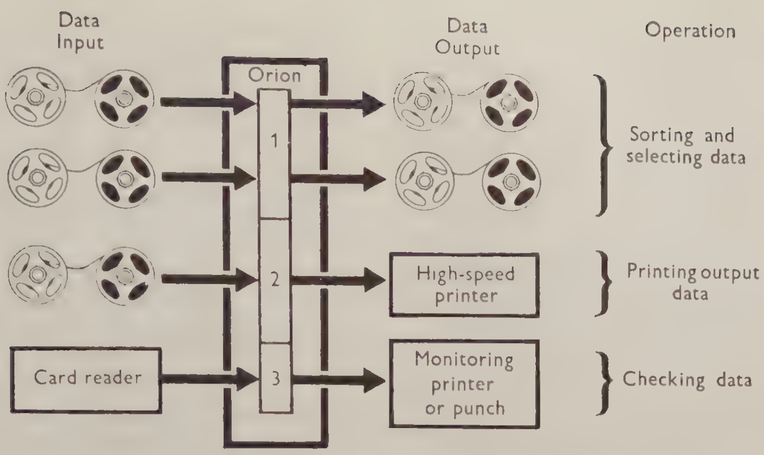
A point that arises with time sharing is that Orion cannot be stopped by a programme instruction. When a programme is completed a note to this effect is printed out by the Flexowriter and the auxiliary units and the storage capacity that were allocated to it are released, leaving everything ready for another programme to be entered. Meanwhile the computer gets on with those programmes remaining in the machine. Thus, unless the power is actually cut off, the computer remains in constant operation. If at any time it is not called on to do useful work, the computer performs a series of permanently stored engineering test programmes.

If, when working on one programme, the machine attempts to use a part of the store or a unit allocated to another programme, work on the programme committing the violation ceases immediately and a notification that this has happened is typed out by the Flexowriter. In the meantime, the computer continues with those programmes remaining in the machine.

Flexowriter

From this description it will be appreciated that the Flexowriter is of greater importance than the typing monitors fitted to existing computers. The Flexowriter is, in fact, the principal method of communication between the machine and the operator. It records all faults, queries and other pertinent operational data. For instance, if a programme is held up because more punched cards need to be fed in or because a reel of magnetic tape needs to be changed, it will type out a request to the operator.

Operational requests and details of faults are typed out on a Flexowriter



Time sharing on Orion—three programmes being performed concurrently

The operation of the Flexowriter and all monitoring procedures are controlled by a special programme that is permanently stored within the machine.

FERRANTI ORION COMPUTER

Number system—binary or 6-bit code
Mode of operation of arithmetic unit—semi-parallel 24 bits in parallel
Average times for arithmetical operations:—
+ or − 36 to 68 microseconds (0·000036 to 0·000068 second)
× 64 to 200 microseconds (0·000064 to 0·0002 second)
÷ 250 to 1400 microseconds (0·00025 to 0·0014 second).
Type of instruction—three address, or two address with modification
Computer word—48 bits
Quick access store—magnetic core. From 4,096 to 16,384 words capacity
Backing store—magnetic drums of 16,384 words capacity, any number of drums may be fitted
Main file store—magnetic tape. Maximum 32 decks. Data read from or recorded on magnetic tape at 90,000 characters a second
Data input —80-column punched cards read at 600 cards a minute
—7-hole punched paper tape read at 1,000 characters a second
Data output—80-column cards punched at 100 a minute
—7-hole tape punched at 300 characters a second
—printed at 3,000 lines a minute with up to 240 characters a line

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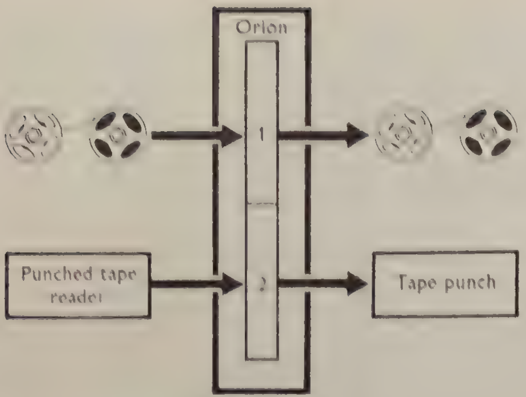
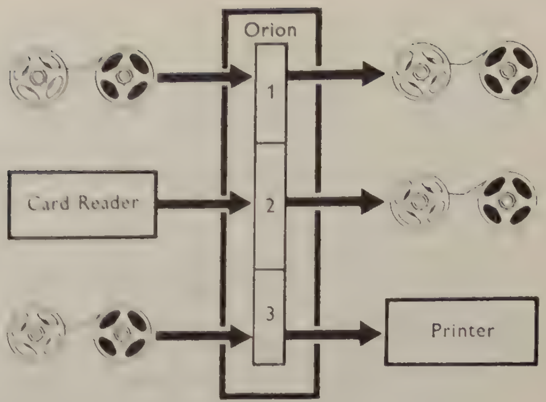
In the accompanying illustration three commercial programmes are shown sharing time on Orion. The first programme sorts and selects data and requires the services of four magnetic tape units and the section, marked 1, of the computer store. Data are read from two magnetic tapes, sorted and re-recorded on two output tapes. The second programme is a data transcription programme. One magnetic tape unit, a high-speed printer and section 2 of the computer store are allocated for this work. Data read from the tape are printed on the appropriate documents. The third and last programme checks data punched in cards for consistency and errors. A punched-card reader, a monitoring printer or punch and section 3 of the store are employed on this task.

The programme with the highest priority starts first and the necessary data are sent to the arithmetic unit. Work on this programme continues until it is held up, waiting for some data to be transferred to or from an auxiliary unit. While this transfer is taking place the programme next in order of priority is started. Maybe a punched card has to be read and, as this takes some time to complete, after this action is initiated the computer begins work on the remaining programme. Whenever the arithmetic unit is not employed on one programme it is immediately switched to the next that requires its services. Similarly, the computer control is constantly occupied transferring instructions and initiating actions according to the demands made by the three programmes.

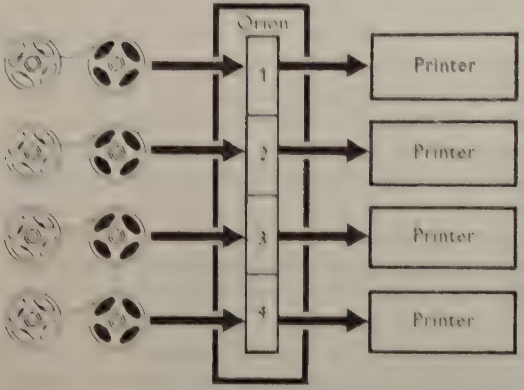
When a programme has been completed, the Flexowriter informs the operator of this fact. All the cards and magnetic tape reels connected



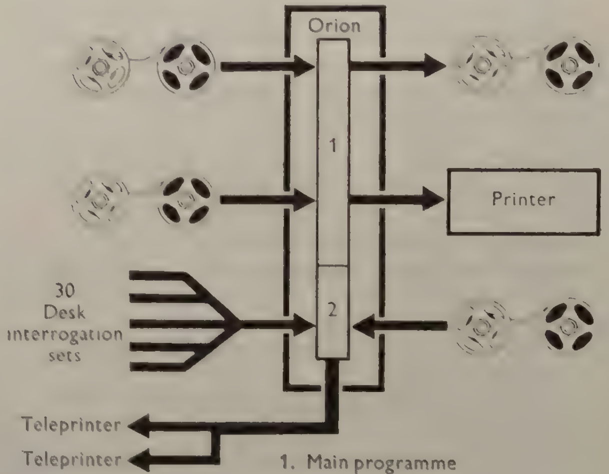
1. Main commercial programme
2. Series of short scientific programmes



1. Main programme
2. Transcription: cards to magnetic tape
3. Transcription: magnetic tape to print



Transcription: magnetic tape to print four operations simultaneously



1. Main programme
2. Random reference to stock and buying records

Four examples of time-shared computer operations

with it are then removed and, if the machine capacity released is sufficient, the next programme is fed into the computer. In the meantime, work on the other two programmes continues. It is not necessary to wait until these are finished before the next programme is read in. Any time the computer has enough free capacity a new programme can be started. Thus at any particular instant the programmes in the computer will all be at different stages of completion.

Where a computer is used principally for commercial work, the great advantage of time sharing is that it enables the auxiliary input-output equipment to be used more efficiently. With scientific work, however, the advantages obtained are somewhat different. Several methods of utilizing the time-sharing capabilities of a computer have been investigated and some typical ways in which these machines can be employed in business and industry will be described.

A feature of scientific or technical work is that new programmes are continually being developed. Consequently, one of the major problems is to provide sufficient time on the computer for programme testing. This is a slow semi-manual procedure for which the services of the computing circuits are only required briefly and intermittently. Time sharing enables a programme to be tested, and where necessary corrected, while the computer is busy with other routine and well-tried calculations.

Of course, many industrial organizations use the same computer for both technical and commercial work. Time sharing enables such an organization to tackle a greater volume of work and perform both types of job simultaneously. One of the best ways of achieving this is to load a large commercial data processing programme into the computer and, while it is carrying out this work, feed in a series of short technical or scientific programmes. This combination of programmes utilizes the capabilities of the machine efficiently, since the commercial programme will make the most use of the data input-output units and the technical programmes will make most use of the arithmetic unit.

Data transcription operations

A useful commercial application is where one data processing and two data transcription programmes are performed concurrently. Again, a lengthy job is chosen for the main programme to keep the computer occupied while the other two programmes transcribe data from punched cards to magnetic tape and from magnetic tape into print.

Usually, in commercial work, considerable quantities of data have to be transcribed and this leads to the next application where the computer reads data from four magnetic tape units and prints four sets of documents simultaneously. This is very useful when large numbers of invoices or bills have to be prepared and posted on a specified day.

The final example is of an application for which one of the first Ferranti Orion systems to be delivered will actually be used. AB Turitz and Company of Gothenburg own 52 retail stores, the largest group in Sweden, and this company is buying an Orion for stock control, purchasing control and other commercial data processing jobs. While the computer is to be used throughout the day on these tasks, one of the magnetic tape units with which it will be equipped is to be reserved to provide the buying department with up-to-date information on stocks held at any time a request for such information is received. Details of the current stocks at each of the Company's 52 stores, together with information on the styles, sizes and prices of the complete range of goods offered for sale, will be recorded on one reel of magnetic tape.

Thirty keyboards are to be located in the offices of the central buying department. When a buyer requires the latest information about a product he will enter the appropriate code number on a keyboard. The request will be transmitted to the computer and the magnetic tape searched. The information required will be read from it, transmitted back and printed out by one of two teleprinters situated in the buying department. The operator will tear off the paper and take it to the buyer who made the request. Thus, within the space of a minute or two, the buyer will be supplied with all the information he requires.

This information request procedure is to be treated by the computer as a time-shared operation with the other jobs that are being handled at that moment. Consequently, buyers will be able to make inquiries at any time of the day without interfering with the main work being performed by the computer. Information on the magnetic tape will be revised at frequent intervals in order to ensure that the information supplied is always up to date. This ability to refer to stock records at random will only occupy a very small part of the computer capacity and consequently will be inexpensive to operate.

The Orion system for the Turitz Company is due to be delivered at the end of 1961 and will cost £280,000. It will be the third machine of this type to be built and the first to be exported. The first two Orion systems will be installed at the Ferranti computing service centres in London and Manchester.

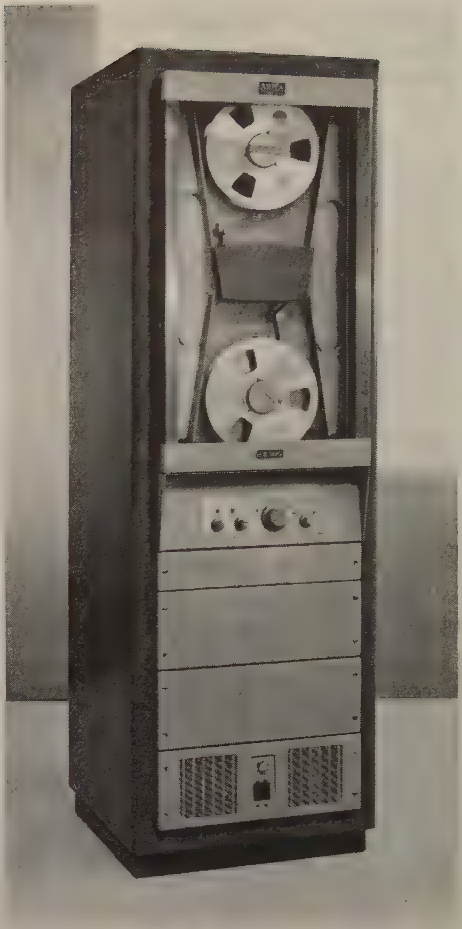
Growth of system

Orion systems cost between £100,000 and £300,000 depending upon the amount of auxiliary equipment needed. The size of an Orion installation can be adjusted to suit the quantity of work to be performed and the system can be expanded easily by adding units. Additions of data input-output units will increase the number of programmes that can be performed concurrently. Extra information-storage capacity can also be provided as the volume of data to be processed grows.

Typical items of auxiliary equipment that are being offered with Orion at the moment are: De La Rue Bull BZ tabulators that print at 150 lines a minute; a new design of I.C.T. printer that operates at 400 lines a minute; Rank Xeronic printers producing 3,000 lines per minute; Creed 3000 tape punches operating at 300 characters a second; teleprinter tape punches operating at 60 characters a second; I.C.T. card punches that perforate 100 cards a minute; I.C.T. card readers that read 600 cards a minute; two types of Ferranti punched paper-tape readers that scan 300 or 1,000 characters a second; and, most important of all, Ampex high-speed magnetic tape recording units.

These can read information from magnetic tape or write data upon it at the extremely high speed of 90,000 characters a second. As many as 32 magnetic tape units may be included in one system and up to four of these units can be operated simultaneously. An Ampex magnetic tape unit is shown on the right.

This rapid data transfer rate is obviously of great value in commercial work. It means that routine clerical operations, such as up-dating file records, can be completed extremely quickly. In fact, in those cases where only a small proportion of the records has to be amended it will be possible, and economically justifiable, to revise the records daily instead of waiting for sufficient alterations to accumulate and doing the job, say, once every three or four days.



Data are read from or recorded on magnetic tape at 90,000 *characters a second by Ampex units*

Characters are read from punched paper tape at the rate of 1,000 *a second by this high-speed reader*

Recording data

Data are recorded on magnetic tape in blocks that can contain any number of computer words. As a computer word contains 48 bits and data are recorded either in alphanumeric form using a 6-bit code or in pure binary notation one word can accommodate a 14-decimal digit number represented by 48 bits, eight alphanumeric characters or a three-address programme instruction. Because a space must be left between adjacent blocks recorded on the tape, obviously

MAGNETIC TAPE DATA TRANSFER RATES

Number of computer words in each block	**Average rate of transfer per second of 6-bit coded characters**	**Rate of transfer of binary data quoted as numbers of equivalent decimal digits transferred each second**
Continuous recording	90,000 (instantaneous data transfer rate	162,000
500	70,000	126,000
250	60,000	108,000

the highest data transfer rates are obtained when the longest possible blocks are used. Typical data transfer rates are given in the accompanying table. It will be noticed that the highest information transfer rates are obtained when numerical data are recorded in pure binary code.

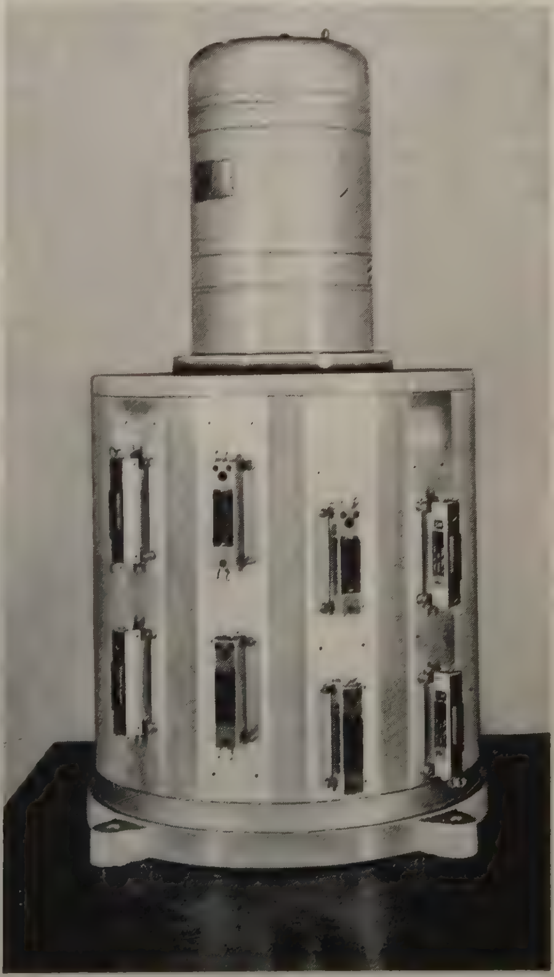
Each reel contains 3,600 feet of magnetic tape. If data are recorded in blocks of 500 words each, one reel can accommodate 2,750,000 computer words. As many items of commercial information are very short, facilities are provided for packing more than one item into each computer word. It is also possible to extract any one item from a computer word.

Magnetic drums are also fitted to the Orion system to provide additional information storage capacity to which rapid access can be obtained. Any number of drums can be connected to a system and each drum accommodates 16,384 computer words.

Another item that can be provided with Orion is a unit that enables "floating point" arithmetic to be performed nearly as quickly as fixed-point calculations.

It is expected that the majority of programmes for Orion will be prepared with the aid of automatic programming systems and it is stated that account was taken of this when the computer was designed so that the maximum benefit could be derived from the use of such simplified programming techniques. Further, Orion is provided with a comprehensive list of instructions to make the task of programming both technical and commercial problems as easy as possible.

Magnetic drum assembly. Any number of these units may be connected to an Orion data processing system



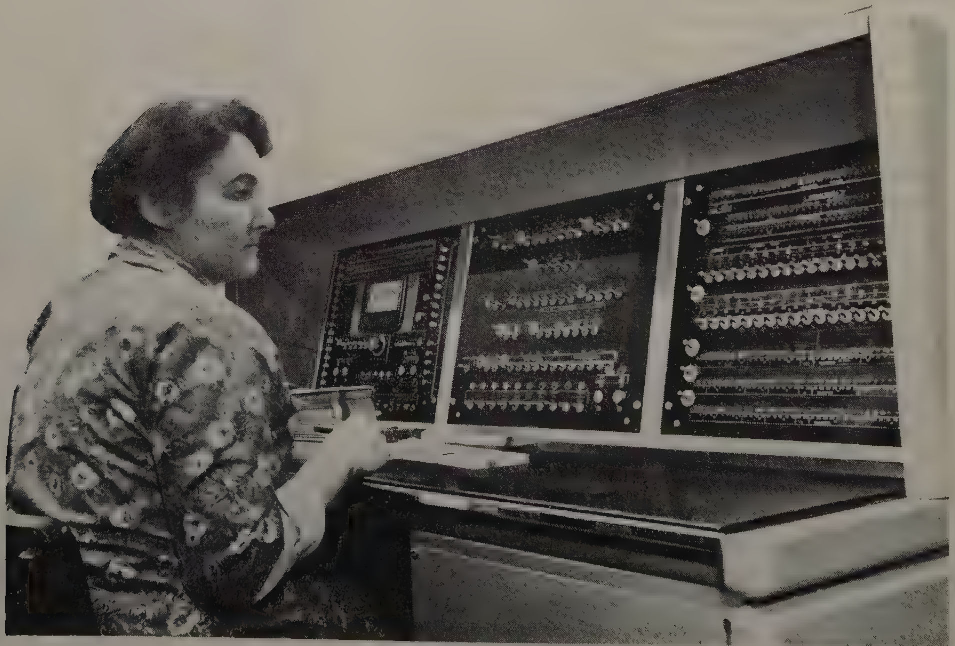
From punched cards to computer —a practical approach

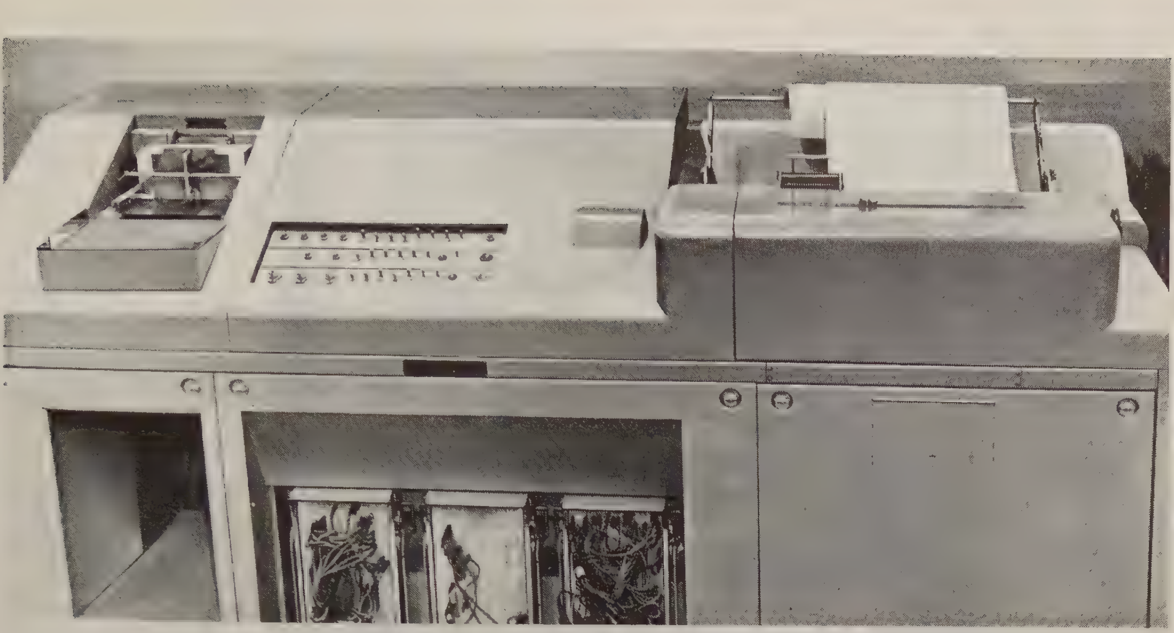
How The Morgan Crucible Company employ a computer on commercial work

It is often said that to use a computer effectively the entire administrative structure of a company must be reorganized to suit the capabilities of the machine. While this may seem desirable, a danger is that the company might languish while the operation is being performed. A more practical approach is to move on to the computer isolated jobs which are both suitable and easily transferred, perhaps jobs already done on punched-card machines and then to extend the work slowly to the other procedures as opportunity offers. In this way a major cataclysm is avoided and valuable practical experience of computer operations is obtained. This is the approach adopted by The Morgan Crucible Company. How this has worked in practice is the subject of this article

OVER 70 I.C.T. Series 1200 computers have been delivered or are on order. And pride of place among business users must be given to The Morgan Crucible Company who were so keen to apply a computer to commercial work that they persuaded I.C.T. (at that time still The British Tabulating Machine Company Limited) to let them have a prototype machine. This was in 1956. Morgan Crucible used this machine on a variety of industrial and commercial jobs for two years, eventually replacing it with an I.C.T. 1201 computer in October, 1958.

Control panel of the I.C.T. 1201 *computer installed at The Morgan Crucible Company*





Computer data input-output unit. Punched cards are read on the left and results are printed on the right

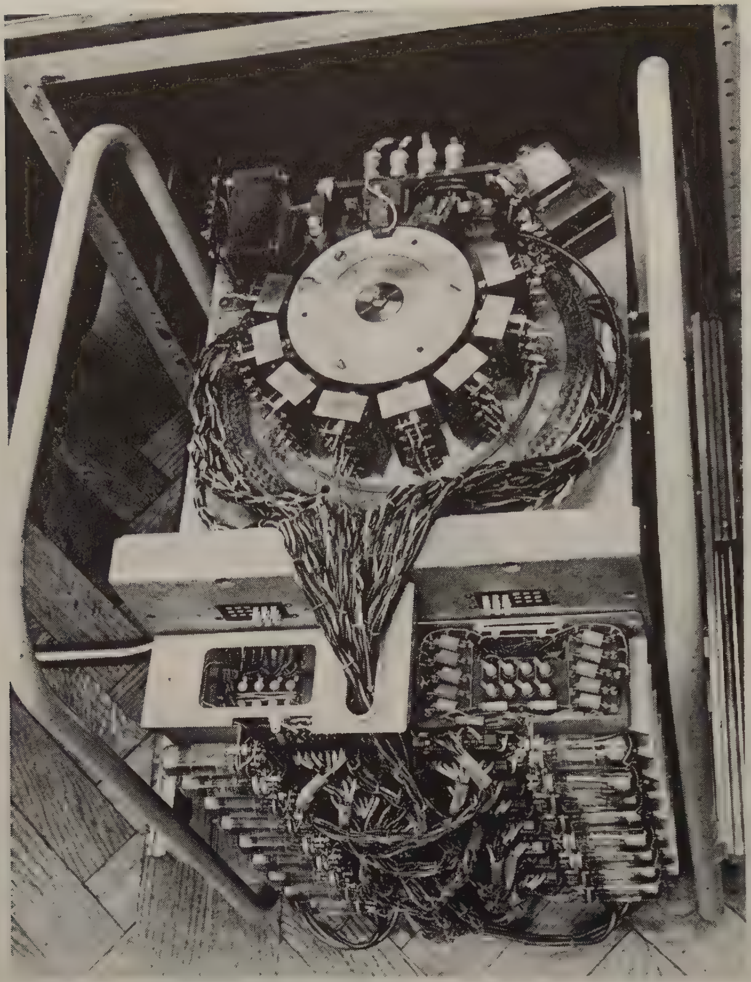
Before consideration of how the computer is employed, the nature of the business carried on by the Company will be described because this, of course, determines the administrative structure created. Established 104 years ago, the Company manufactures and fabricates components from carbon in all its varied forms. Two of the principal products are carbon brushes for electrical apparatus and, as the Company's name suggests, crucibles. Many thousands of products are made in a wide range of varieties. Consequently, all items are manufactured in small batches; mass production flow-line techniques are only used on a limited scale. As a result, the Company comprises a large number of small specialized departments.

Export sales account for 40 per cent of the production of the main factory at Battersea, in London. In addition, the Company has established and operates factories in 11 other countries. In fact, it was through its subsidiary in New York that the parent company first became interested in electronic computers.

Within an organization of this type it is obvious that the handling and dissemination of information presents a major administrative problem. Also batch production means that a considerable amount of planning and coordination is required. In the 1930s Hollerith punched-card machines were introduced to cope with this work, and by 1950 over 50 separate punched-card procedures had been established. The majority of these were interlinked or "integrated," to use the current technical term. In 1952 the decision was taken to investigate the possibility of using a computer for this work.

In 1956 the prototype Hec 4 computer was obtained. This machine was soon put into service preparing the weekly payroll, monthly salary lists and statements. The experiment was successful except that, as might be expected with a prototype machine, servicing time was disproportionate to working time—the machine did not stand up too well to long runs. However, as the utilization rates given later will show, these faults have now been eliminated from the Type 1201 computer which was developed from this prototype machine.

Although the I.C.T. 1201 computer, now in use, has increased the power and scope of the data-processing installation, it is regarded as an integral part of the existing punched-card equipment. With the aid of a computer it is now possible to complete, in one operation, calculations that were previously performed as a sequence of separate operations on two or three different punched-card machines. From this it is apparent that one of the principal applications of the computer at Morgan Crucible is to take over jobs previously done on punched-card machines. Costs are reduced because although the expense of running the computer is three times higher, the work is completed in a quarter of the time. In addition, only one operator is



The magnetic drum fitted to an I.C.T. 1201 *computer can store* 1,024 40-*bit words*

I.C.T. 1201 COMPUTER

Information is read from standard 80-column punched cards and results may be either punched in 80-column cards or printed directly on to the required documents. Cards are read and punched at speeds of up to 100 a minute and data may be printed at 100 lines a minute. Each line may contain 100 characters. Data are handled within the computer in binary form. Conversion of input data from decimal or sterling values into binary numbers is performed automatically as also is the reverse conversion from binary into the appropriate output code.

The I.C.T. 1201 computer is no longer in production; it has been replaced by the I.C.T. 1202. These two machines are similar, the major difference being that the magnetic-drum information store of the Type 1202 has a greater capacity, holding 4,096 computer words instead of the 1,024 computer words of the Type 1201.

I.C.T. 1201 COMPUTER CHARACTERISTICS

Numbering system—binary
Mode of operation of arithmetic unit—serial
Average times for arithmetical operations:—
+ 2·5 milliseconds (0·0025 second)
× 20 milliseconds (0·02 second)
÷ 50 milliseconds (0·05 second)
Type of instruction—two address
Word length—40 bits

Information store—magnetic drum of 1,024 words capacity
Data input —80-column punched cards read at 100 a minute
Data output—printed at 100 lines a minute with up to 100 characters per line
—80-column cards—punched at 100 a minute

needed in place of the four or more operators required to run the punched-card machines.

In the past it has been fashionable to decry using a computer on mundane commercial work, such as payroll, because, it was said, only "integrated" data processing would prove profitable. While not disputing the advantages to be gained from "integration," Morgan Crucible believe that very few jobs are unsuitable for the computer. The Company also believe that it is only by performing on a computer certain routine administrative work, piecemeal if need be, that the necessary experience can be gained that will eventually lead to integrated data processing. No job is considered too small for the computer, provided it can be done quickly and efficiently.

One of the factors that influences this outlook is that the more work performed on the computer the less there is left for the existing punched-card installation to do; consequently, machines can be dispensed with and the annual hire charges reduced.

As already stated, the I.C.T. 1201 computer was installed at the Battersea works in October, 1958. Its time is occupied in the following way. Each week it is used for 5 hours on payroll, 2½ hours on payroll analysis, 1 hour producing a production progress report for the carbon brush department and for 3½ hours on invoice summaries—a total of 12 hours. In addition, once a month the computer is used for 4 hours on salary calculations, 16 hours on salary statements, 4 hours on special statements, 4½ hours on calculations connected with the factory production incentive scheme, 2½ hours on analysing sales and 4½ hours on sales summaries—a total of 35½ hours. The computer works, on average, 20 hours per week.

It has been emphasized that The Morgan Crucible Company prefers to prepare simple programmes and get them running on the computer. Two of these programmes will be described in detail to show the type of work tackled and the reasons for doing these particular jobs.

The first application is the preparation of a production progress report for the carbon brush department. This job could be done quite well on conventional punched-card machinery except for one thing—time. The report is compiled from data recorded on punched cards known as order cards. These cards are progress documents in constant use within the carbon brush department. As a result the department can only spare them for data processing purposes for a very short time. This is where the computer proves valuable. Within one hour, all the cards, numbering 4,500 approximately, are collected from the department, passed through the computer and returned.

Many thousands of different types of carbon brush are made, of which only ten per cent are of a standardized design. With this extensive range it is not possible to maintain a comprehensive stock and so brushes are manufactured to meet customers' orders. As each order is received the sales department prepares a typed factory order which provides the authority to manufacture. In addition, the sales department sends to the card-punching room a second document containing the following data: the serial number of each order, the number of the week during which delivery is to be made, the quantity required, value and the product category. Although many different types of carbon brush are manufactured, they are grouped into ten categories and each category is further sub-divided into two classes—A or B. Each of these categories is given a product code number.

A punched card is produced for each item listed on an order and the key punching section prepares approximately 400 order cards a day. These cards are sent to the carbon brush department where they are sorted according to the delivery week and then filed away in order-number sequence. These are the cards that are used as progress documents. As the work proceeds, information regarding the various manufacturing operations that are finished is recorded, in writing, on the back of the card.

When a job is completed, the appropriate card is removed from the file and returned to the punched-card machine room. Here the cards are passed through a tabulator to produce a printed list of completed orders.

Once a week, at 4.0 p.m. on the Thursday, all the order cards in current use are collected; their sequence is not altered in any way. As each card passes through the computer the week, category and quantity are read from it. This information is recorded on the magnetic drum of the computer, where progressive totals are kept of each category of brush being manufactured and the number of orders involved.

After the last card for a particular delivery week has been read, the computer prints a list that specifies the gross quantities of each category of brush outstanding and the number of orders involved. Similar data are derived for all the other weeks. Then the cards are returned, still in the correct sequence, to the department.

The document produced provides management with a picture of the future production load on the carbon brush department and also highlights those orders that are behind schedule.

In addition to the procedure described, the order cards are used for one further purpose—to assess the value of the work-in-progress. Once a month the cards are run through a tabulator and the total value of all the orders is compiled. For this purpose the total value of each individual order is punched in the card. Where orders are still incomplete, a proportion of the total value is taken. The proportion is determined by the number of "points" recorded on the card. Points are allocated in accordance with the stage of manufacture reached. These values are marked in pencil on the cards and are converted into punched holes by a mark-sensing punch.

Although this is a simple data processing sequence, it illustrates how advantage can be taken of a computer's speed and information storage capacity to avoid disrupting an existing administrative routine. Further, within one hour a complete summary of the carbon brush department's production progress file is available in a concise and readable form.

If this job were done on punched-card machines, the cards would be required for at least three to four hours and more operations would have to be performed. First, the cards would have to be sorted into brush category order, then tabulated to produce the totals for the production progress list. Finally, the cards would have to be re-sorted back into the original sequence in which they were obtained from the carbon brush department. Not only would handling time be longer, but, in addition, more operators would be needed and the risk of cards being lost or misplaced would be greater.

Another job performed on the computer that is tedious to do on conventional punched-card machinery is assessing the number of manhours worked each week—information needed for the factory incentive bonus calculation.

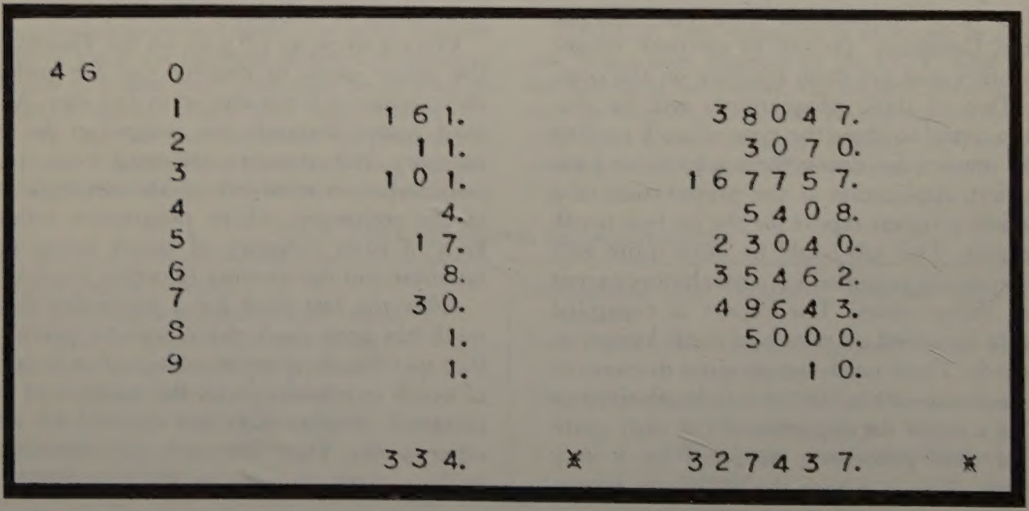
All production employees are paid a flat rate bonus proportionate to the total value of the work performed in the factory. An hourly bonus rate is calculated and payments are based on the total number of hours worked by each man. Two basic rates of bonus are paid: one to hourly-paid adult workers and two-thirds this rate for pieceworkers. Juniors receive 60 per cent of the adult rates.

Hourly-paid workers receive a proportion of the bonus each month and the remainder at the end of the year. Pieceworkers receive their bonus in one lump sum at the end of the year. The production year finishes at the end of October and the annual payments are made early in December.

In order to be able to specify the hourly bonus rate, first the total number of manhours worked by the entire factory staff must be compiled. This is the job for which the computer is used.

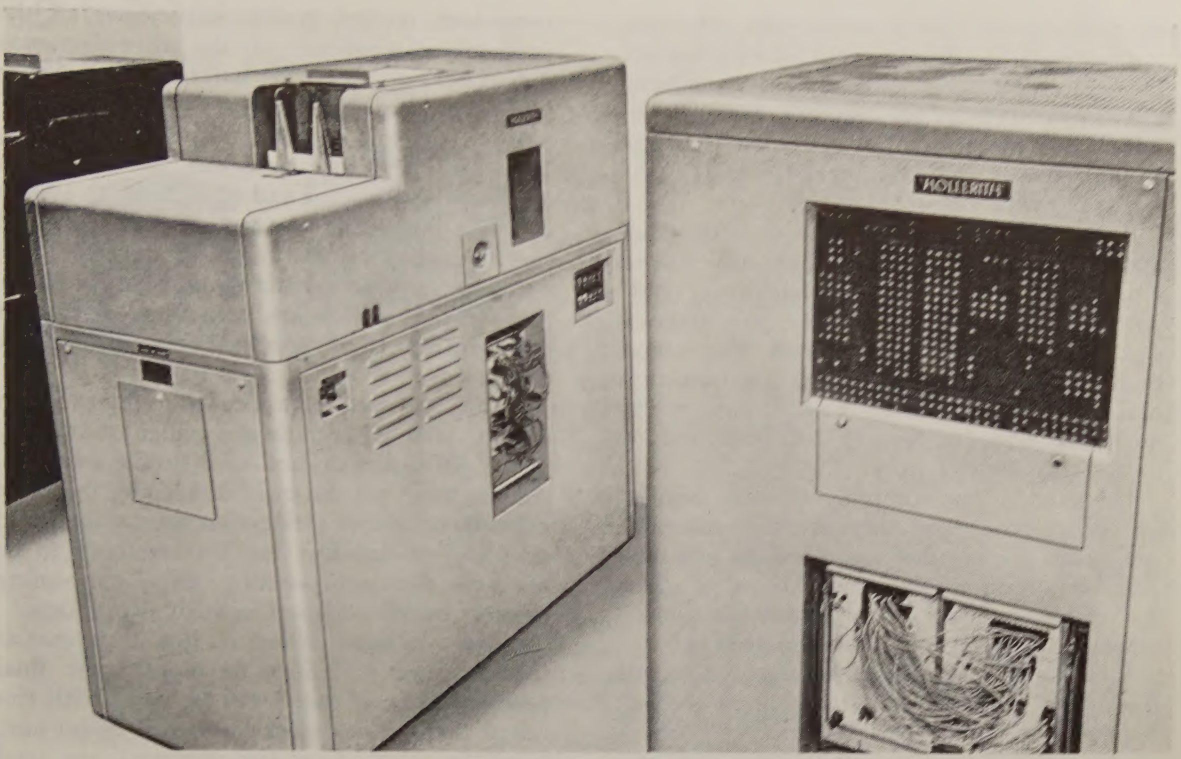
The total hours worked each week by each employee is already recorded in punched cards prepared when the weekly pay was being

Part of the carbon brush department progress report. Reading from left to right: week number, production category number, number of production orders involved and number of brushes to be manufactured



```
 4 6    0
        1          1 6 1.            3 8 0 4 7.
        2            1 1.              3 0 7 0.
        3          1 0 1.          1 6 7 7 5 7.
        4              4.              5 4 0 8.
        5            1 7.            2 3 0 4 0.
        6              8.            3 5 4 6 2.
        7            3 0.            4 9 6 4 3.
        8              1.              5 0 0 0.
        9              1.                  1 0.

                   3 3 4.     *    3 2 7 4 3 7.     *
```



Bonus pay calculations are performed on an I.C.T. 542 multiplying punch

calculated. These cards are kept and once a month they are sorted into numerical order. The numbers punched in these cards indicate the department and clock number of each employee. Next a group of summary cards, on which are recorded the accumulated hours worked to date by each employee, is collated with the payroll cards.

The cards are now arranged in a sequence of separate packs—one pack for each man. Each pack may contain five or six cards and these cards provide the input data for the computer.

All the hours worked during the preceding month are added to the year's total to date and this information is punched in the summary card. Another item of information punched into the card is the total hours worked in the preceding month. In addition, a list is printed of the total manhours worked that month in each department and, finally, a grand total for the factory. With this latter figure the accounts department can calculate the appropriate hourly rate for the bonus.

Cards for hourly-paid workers are then sorted into two classifications—adult or junior. Then the hourly bonus rate is entered as a constant factor into an I.C.T. 542 multiplying punch and the sets of summary cards are passed through. Hours worked in the preceding month are multiplied by the bonus rate and the bonus for the month is punched into each card. These cards are then used to enter details of the bonus due into the next payroll sequence when it is run.

A similar procedure is performed each month for piecework bonus payments, but in this case the amount is credited to the man and carried forward from month to month until the end of the year.

As stated, only a certain percentage of the bonus due is paid to hourly workers each month. At the end of the year another calculation is performed similar to that already described to obtain the yearly aggregate of bonus due to these workers.

In an actual running time of 3¼ hours the computer calculates and records the monthly hours worked and the new accumulated yearly totals for each of 2,000 employees in 50 different departments and at the same time prints departmental and gross totals.

An advantage of using a computer on this particular job is that because a complete printed list of departmental totals is produced, it is so much easier to check the figures. If the job was done on conventional punched-card machines, this particular document would not be prepared. Incidentally, it is estimated that the computer is twice as fast as the equivalent tabulator-summary punch assembly when used for up-dating records and summary punching the results in cards.

Before the computer starts on the day's jobs, a test programme is performed. This takes about a quarter of an hour and the machine is ready for work by 8.45 a.m. Routine maintenance occupies about eight hours a week. There have been comparatively few breakdowns and most of these have been failures of mechanical equipment, but none has been of sufficient duration to upset the flow of work.

However, as the computer is only occupied for 20 hours each week there is still considerable spare capacity for other work. Several new data processing routines are being planned of which the most ambitious is a production control scheme for the carbon brush department.

Like many other companies, Morgan Crucible discovered that the longest and most difficult operation in applying a computer to administrative work is the initial investigation and planning of the data processing procedures. This phase is also one of the most rewarding because it brings to light duplicated operations that have been grafted on to the main clerical procedure, often to meet special circumstances that no longer apply. It also highlights duplicated products or ones so similar that they can be combined. For instance, it has been possible to make a useful reduction in the variety of items manufactured in the crucible factory.

Before an investigation is started, however, one of the big problems is to choose the right man to carry it out. In the case of the production plan for the carbon brush department the assistant manager of the department was appointed—first, because it was considered necessary that all future executive staff should have a real knowledge of data processing techniques and, secondly, because it was felt that, if chaos is to be avoided when the new procedure is introduced, experience of the production problems of the manufacturing department was of greater value than experience of data processing.

Work on this problem started in January, 1959, and the first task was to establish a comprehensive costing and reject analysis system as this is by far the best way of discovering all the pertinent facts and figures about a production process. Once a satisfactory plan for handling the information has been evolved it is not expected that the programme for the computer will take long to write.

A slow and cautious approach to this problem is being adopted because it is evident that many of the difficulties do not have simple solutions. Among these are the tasks of keeping the basic information about production constantly up to date and of deciding the best methods to be adopted for incorporating data concerning changes in the design of individual products.

In view of these difficulties it is likely that at first a much simplified version of the final production programme will be run. With this initial programme, stock levels will be set and, from the sales information received, the total numbers of items that require to be produced in each of the succeeding weeks will be calculated. The actual sequence of manufacture and the loading of the work on to the carbon brush department may still be done manually.

Up to the present time the direct financial savings made as a result of employing a computer on routine administrative work have been marginal, but the experience gained has been considerable. In contrast, the indirect savings have been appreciable. For example, as a consequence of the investigations resulting from the introduction of a computer the number of products manufactured has been reduced and new and more economical systems of stock control have been introduced. Nevertheless, as more work is loaded on to the computer and more programmes successfully developed it is confidently expected that the ratio of administrative costs to production costs will diminish.